U.S. ARMY

MEDICAL SUPPLY SERVICES SCHOOL
St. Louis

TEXT BOOK

VOLUME 1

X-RAY

SECTIONS 1 TO XXXV

This publication has not been officially approved by the War Department. It has been prepared and is issued for instructional purposes only.

TABLE OF CONTENTS

FOREWORD

The Medical Supply Services School Text Book has been prepared to give the student a background of fundamental principles and elementary physics, as well as detailed information on the operation and upkeep of equipment and apparatus used by the Medical Department of the Army. So that it may also be used as a satisfactory book of reference by the graduate of this school in the field, complete and specific instructions for installation, operation and service for as many as possible of the various types and makes of equipment have been included.

When necessary to give the student a proper idea of the purpose or use of the apparatus, the technic of medical application has been touched upon briefly. Otherwise, it has not been presented or discussed.

Material for the book has been obtained from many sources. The generous cooperation of the manufacturers of equipment has provided the greater part. This text has been prepared to help the student with his work in the field and is to be utilized as a guide and reference.

MEDICAL SUPPLY SERVICES SCHOOL
St. Louis, Missouri

ROYAL K. STACEY,
Colonel M.C., U.S.A.,
Commandant.

November, 1943

SECTION I

MATTER, ENERGY, AND THE ELECTRON THEORY

GENERAL - To obtain an understanding of the conditions affecting, the probable reasons for, and explanation of, electrical phenomena it will be necessary to study the structure of matter.

MATTER - Matter is anything which occupies space, that has weight and dimensions. In general, the existence of matter may be detected by the senses - by seeing, feeling, tasting, and smelling. Some kinds of matter are invisible - for example pure air, illuminating gas, and oxygen - but since they occupy space and have weight they are matter. Matter, therefore, can be described as the technical name for all things tangible.

ENERGY - Energy is intangible. It can be represented by its effect on matter and can be defined as the capacity for doing work. Energy can take on various forms, such as mechanical energy, chemical energy, heat energy and electrical energy. Any of these forms can be transferred from one form to another. In a limited system, there has never been an observation of a loss or gain in the total energy. This is known as the law of conservation of energy. To state this law another way, "Energy can neither be created nor destroyed". It is sometimes convenient to approach the study of electricity from an energy viewpoint. The law of conservation of energy should always be borne in mind.

Electrical energy can be divided into three general classifications - static electricity, dynamic or current electricity, and magnetism. Each can be converted into the other. Energy is measured by its effects on matter. These effects are usually such as to produce motion. From this viewpoint, the unit for energy is equal to the force necessary to produce the motion multiplied by the distance the object is moved - hence, the expression "foot-pounds". The unit of electrical energy, although it could be expressed in foot-pounds, is expressed in "joules". The joule is used to arrive at other fundamental electrical units.

ELECTRON THEORY - Electricity is a physical agent which is present in the atomic structure of all matter. All matter is composed of minute particles, negatively charged, called "electrons", and positively charged particles called "protons".

The construction of matter is now well understood. Matter is not a homogeneous (having the same nature) structure. Matter is composed of a great many discreet, distinct or separate - material particles with spaces between them. Matter is said to be made up of very small particles called "molecules". A molecule is a natural particle of matter which is composed of two or more atoms.

Matter, which is composed of only one kind of atom, is an element. There are 92 different elements. Copper, carbon, and iron are a few examples of elements.

Matter which is composed of more than one kind of atom is called a "compound". Most of the substances in the world are compounds.

Until recently, the atom was thought to be the smallest subdivision of matter. The "electron theory", advanced in recent years, explains much of the observed electrical phenomena. According to this theory, the atom is not the smallest subdivision of matter. Each of the 92 different kinds of atoms is composed of electrons and protons.

All matter is described as being composed of two things, electrons and protons. The electrons, and protons from one element are identical to those from any of the other elements. The only difference between the different elements is the arrange-

ment and number of the electrons and protons, the electrons and protons of all 92 elements are identical.

The electron is the smallest negative charge of electricity known.

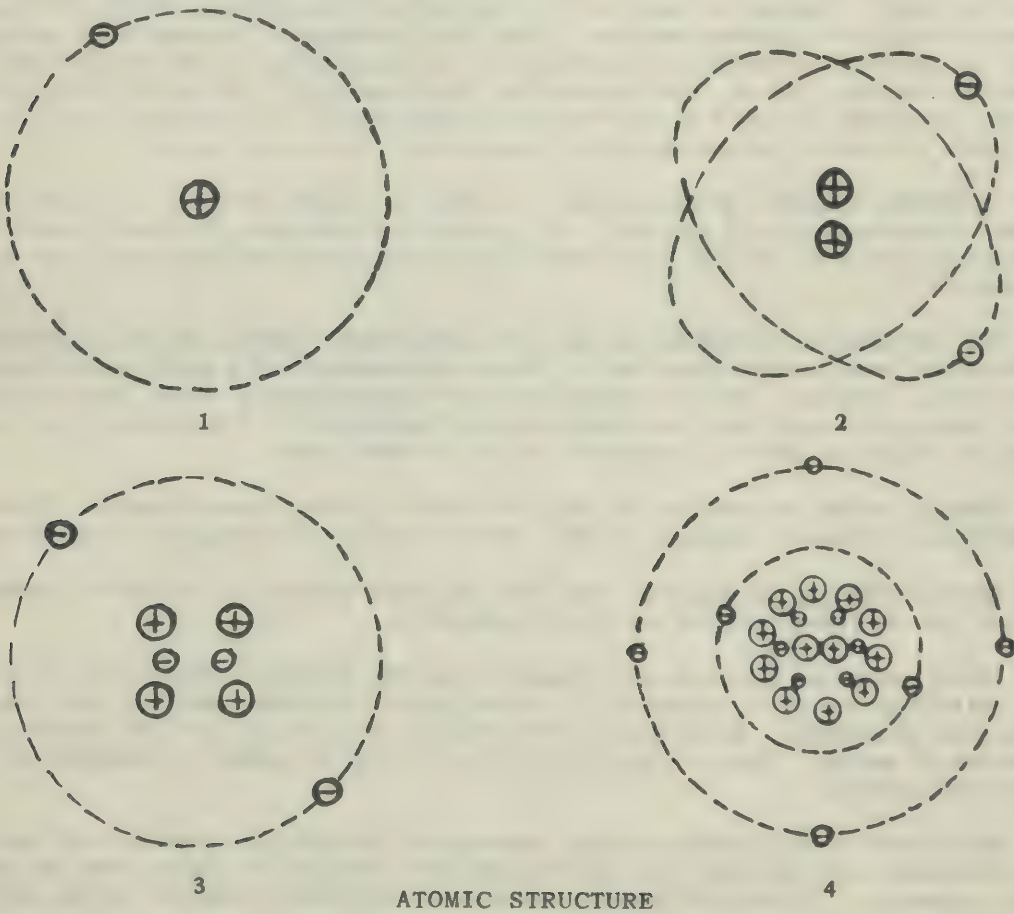
The proton is a small, positive charge of electricity.

The electron and the proton each have the same intensity of charge, although the mass of the proton is believed to be much larger than the electron.

The proton has been described as being composed of a positron and a neutron, the positron having the same mass and charge as the electron and the neutron having no electrical charge.

The protons form a positive nucleus around which the electrons rotate. The hydrogen atom has the simplest structure. It has one proton as the nucleus and one electron rotating about it.

The following figure illustrates several of these atom structures. Figure one (1) shows the simplest atom; Figure two (2) and three (3) are atoms with a slightly more complex structure; Figure four (4) represents a carbon atom. Note that in Figures three (3) and four (4) there are a few electrons trapped inside the nucleus. These are called "nuclear electrons".



ATOMIC STRUCTURE

The atomic structures of the 92 different elements have different properties. Some are hard, others soft; some will burn, some will not. The physical and chemical properties, and the electrical properties of matter, are determined by the structures of their atoms.

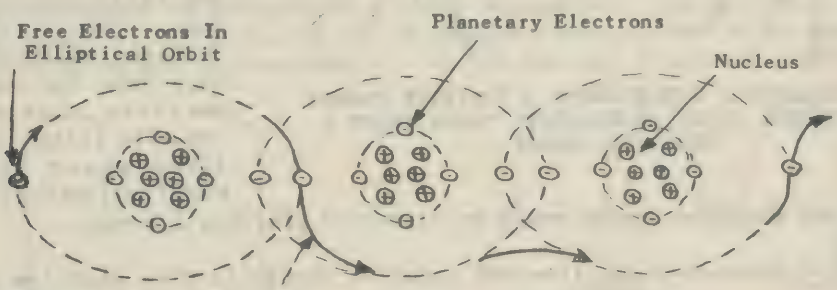
Of their many electrical properties, two will be considered, Conductance and Resistance.

Conductance is the ability of a substance to conduct electricity (allow electrons to flow).

Resistance is a measure of opposition (oppose flow of electrons).

Electricity is described as a flow of electrons. The protons (positive nucleus) being heavier and, too, being down inside the atom, do not flow. Many electrons rotating close to the nucleus, never leave the atom. These electrons are known as "Planetary electrons".

Other electrons rotate at relatively greater distances from the nucleus, in elliptical orbits such that the orbits of one atom over-lap the orbits of the next atom. The electrons not tightly attached to any one atom are known as free electrons. The following illustration shows how these free electrons may travel from atom to atom.



POSSIBLE PATH OF FREE ELECTRONS

The relative number of free electrons has a definite bearing on the conductance or resistance of the material. The substance with the greatest number of free electrons will have a high conductance, thus it will be a good conductor. A substance with practically no free electrons is called a "Non-Conductor or Insulator".

STATIC ELECTRICITY - Static electricity was once considered to be electricity at rest. However, since electrons and protons are considered the ultimate charges of electricity, and since they are always in continual motion, it might be better to consider static electricity as being electrically associated with insulators or dielectrics.

Bodies can be charged with static electricity by various methods. A charged body merely means that the object has more or less than its normal number of electrons. In the uncharged state, each atom has an equal number of electrons and protons. It is only necessary to remove some of the electrons rotating outside the

nucleus in order to charge the body positively. Thus, an excess of protons will exist, since some electrons have been removed. The electrons thus removed will be found on some other object. That object, with an excess of electrons will then be considered negatively charged. Charged bodies act upon one another. Like charges oppose, unlike charges attract. The force of repulsion or attraction changes with the magnitude of the charges and the distance between them. Charged bodies attract or repel each other with a force directly proportional to the product of the charges, and inversely proportional to the square of the distance between them.

The practical unit of charge is called the "coulomb". The coulomb is equal to the charge on 6.28×10^{18} electrons. (6,280,000,000,000,000,000 electrons).

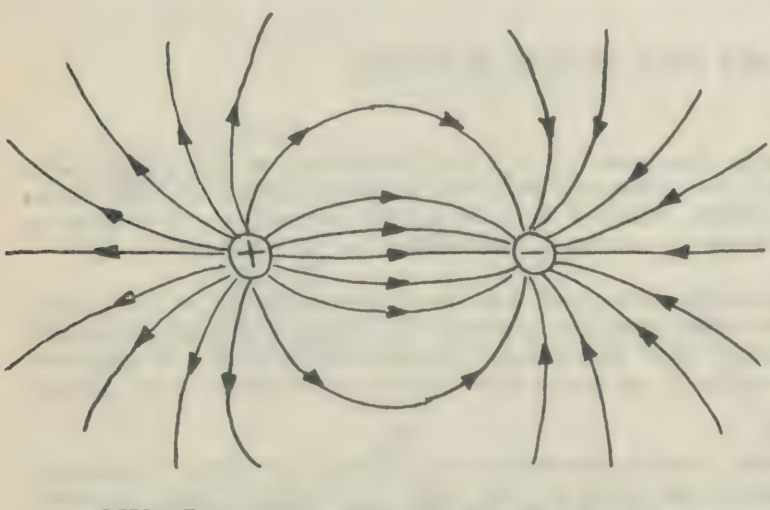
ELECTROSTATIC OR DIELECTRIC FIELD OF FORCE - The electrostatic or dielectric field of force is that region surrounding and between charged bodies.

Fields of force permeate the space surrounding certain objects.

LEFT, DIELECTRIC FIELD ABOUT A POSITIVE CHARGE (ELECTRON); RIGHT, DIELECTRIC FIELD ABOUT A NEGATIVE CHARGE

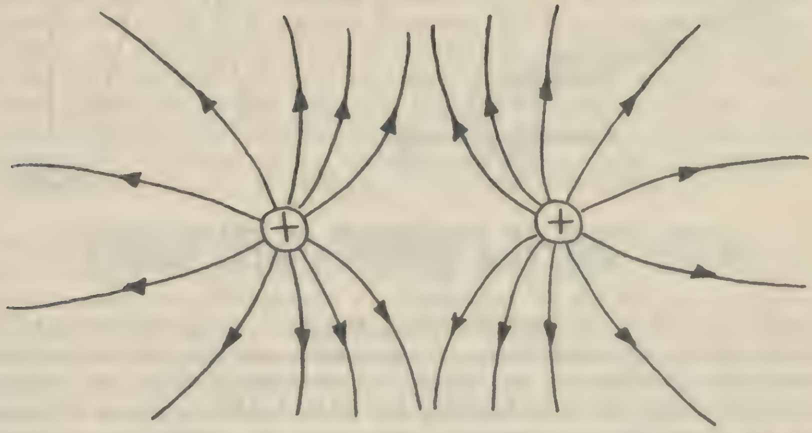
To understand the properties of fields of force it is convenient to represent them by lines of force. Lines of force are imaginary lines used to represent the intensity and direction of the field under consideration. The field about an isolated positive charge is away from the charge, and a positive charge would be repelled (Likes repel). The field about an isolated negative charge is toward the charge and positive charge would be attracted (Unlikes attract).

The field between a positive and negative charge is from positive to negative for the same reason. The following illustrations show the dielectric field about isolated charges represented by imaginary lines of force. Note that the lines of force apparently repel each other. In the case of unlike poles, although the two charges are attracted, the lines of force between the two are not parallel but bulge out at the center as if they were repelling each other. Even though these lines of force are in the same direction, they tend to repel one another. In the case of like poles, see following illustration, the lines



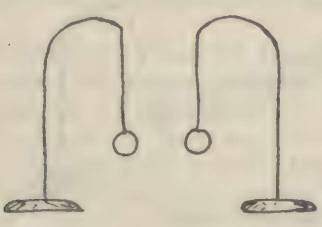
DIELECTRIC FIELD ABOUT TWO UNLIKE CHARGES

of force repel each other. These particular lines of force are likewise in the same direction.



DIELECTRIC FIELD ABOUT TWO LIKE CHARGES

CHARACTERISTICS OF DIELECTRIC FIELDS - Examples: If a rubber rod or comb is briskly rubbed with a piece of fur or woolen cloth, a number of electrons from the fur or cloth adhere to the rubber. If the two are separated immediately, the



PITH BALLS UNCHARGED

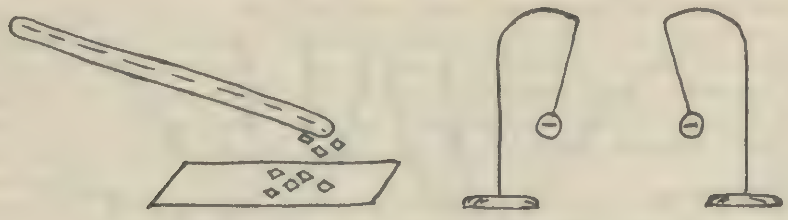
ATTRACTION BETWEEN OPPOSITE CHARGES

rubber has an excess of electrons, or is negatively charged. If two pith balls not electrically charged are placed opposite each other; they will remain stationary as shown in the illustration to the left. If two pith balls are oppositely charged by touching one of them with the rubber and the other with the cloth or fur used in the foregoing example, they will have an attraction for each other showing that a force is present. This is shown in the illustration to the right.

In this latter example, a dielectric field has been established. It was necessary to do work against the force of attraction in separating the charged bodies, but this energy would be regained if the bodies were allowed to come together as a result of the force of attraction between them. Hence, energy may be stored in a dielectric field.

If the negatively charged rubber rod be moved a great distance away from the cloth or fur, a dielectric field still exists in the space around it. This may be demonstrated by picking up bits of paper with the rod or by charging both of the

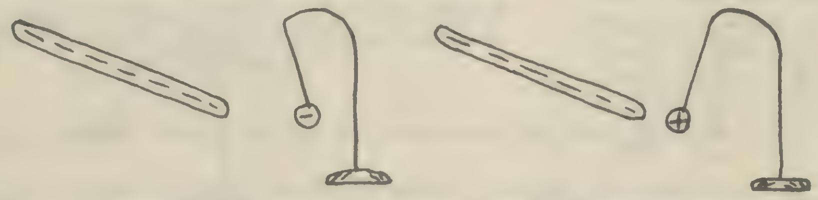
pith balls from it. The pith balls now show a force of repulsion between them. This is still a dielectric field, and illustrated in the following diagram.



LEFT, FORCE OF ATTRACTION OF CHARGED ROD;
RIGHT, REPULSION BETWEEN SIMILAR CHARGES

If an external force is used to bring the two charged pith balls closer, work is done and the force of repulsion is increased, or the field is increased. The energy consumed in increasing the field is recovered when the external force is removed. It will be used up in returning the pith balls to their original positions. Here again it is shown that: energy is necessary to establish or increase a field, force is necessary to maintain it, and recoverable energy is stored in the field.

If one negatively charged pith ball is isolated and the negatively charged rubber rod is brought up toward it from any direction, a force of repulsion will be shown to be present. If the pith ball had been positively charged, a force of attraction would have been noted, no matter from which direction the negatively charged rod approached. These effects are illustrated below.



EFFECT OF FIELD ABOUT A CHARGED BODY

The conclusion, then, is that a dielectric field entirely surrounds a charged body.

POTENTIAL - Potential is a term for potential energy and represents energy due to position. The water at the top of Niagara Falls possesses an enormous amount of potential energy due to its position. This potential energy is converted into kinetic energy as it falls. The amount of potential energy a certain quantity of water has at the top of Niagara Falls is equal to the work necessary to move that amount of water from the center of the earth to the top of the falls. This potential energy is really stored in the earth's gravitational field. Similarly, a point located in a dielectric field can be considered to possess an electrical potential or potential energy due to its position in the dielectric field, and can be measured by the work required to move a unit charge from infinity up to that point. If work must be performed in moving a positive charge up to that point, the point in question is at a positive potential. If work must be performed to move a negative charge to the point, it is at a negative potential. From the above consideration it can be seen that the units for potential are work or energy units per unit charge.

In the case of electrical potential, volt was adopted as the unit and equals one joule per coulomb.

In practice, it is not the absolute potential that we are interested in but the difference of potential. In the case of Niagara Falls it is not the work that would result if the water at the top were to return to the center of the earth—this would represent the absolute potential of the water at the top; the problem is the work that results when the water moves from the top to the bottom of the Falls. Numerically, this is equal to the difference between the potential at the top of the Falls and that at the bottom. Likewise, in electricity it is the difference in potential between two points that is of importance.

This difference of potential is measured in volts and is equal to the work or energy necessary to move a unit charge from one point to the other point. If a unit charge is free to move, the difference of potential is equal to the energy expended by the field in moving the unit charge from one point to the other. In practice the only charges that are free to move are the free electrons in a conductor. If the ends of a conductor are connected to points which are not at the same potential, the free electrons will move or flow toward the higher potential. That is, if one end of the conductor is connected to a point of negative potential and the other end to a point of positive potential, the free electrons will flow from negative to positive until both points are at the same potential. On the other hand, if both points are at a positive potential, then the free electrons will flow from the lower positive potential to the higher positive potential until both points are at the same potential. Likewise, if both points are at a negative potential, the free electrons will flow from the point at the greater negative potential to the point at the lesser negative potential until both points are at the same potential. In other words, the free electrons will flow as long as there is a potential difference and a conducting path. This flow of free electrons in a conductor is called an electric current.

If no work is required to move a unit charge from infinity to a certain point, then according to the definition of potential that point is at zero potential. To find a point at zero potential, it would be necessary to go an infinite distance from all charges to get out of their dielectric field. It can be seen from the above that absolute zero potential has no practical meaning, but since there can be a positive and a negative potential there should be some place to refer to as zero potential.

In the case of mechanical potential energy, the water at the top of Niagara Falls would have to flow down to the center of the earth to be at zero potential. This is also impractical, so it was arbitrarily agreed that the largest portion of the earth which was at the same level, and hence the same potential, would be called zero level. This is sea level, for the oceans cover the majority of the earth's surface and are so large that millions of gallons of water can be removed or added without appreciably lowering or raising this level.

If a large conductor could be connected, an immense quantity of electricity could either be removed or added without appreciably raising or lowering its potential. The earth's crust is just such a conductor. For this reason the earth has arbitrarily been chosen to represent zero potential. To put some object at the potential of the earth (zero potential), a good connection must be made to the soil moisture by connecting to a large water pipe system or to a large amount of buried conducting material. This is referred to as GROUND by the practical electrician. Most all electrical installations are grounded at some place.

Another example of a relative zero value is zero temperature. When zero is

reached it does not mean that it can get no colder. It only means that the temperature has reached a value which a group of men arbitrarily agreed to call zero. In one system it is the temperature of melting ice.

ELECTROMOTIVE FORCE (e.m.f.) - Electromotive force and electrical pressure are other terms used to express a difference in electrical potential. Electromotive force is the force that causes electricity to move through a conductor. As it is electrons that move, e.m.f. might better be called electron moving force which is nothing more than a dielectric field of force such as exists between points of different potential. Hence, a potential difference (p.d.) and an e.m.f. represent the same thing.

In the early days, electricity was considered to act like a mythical fluid that flowed through the wires similar to water flowing through a pipe. From this viewpoint, a pressure was required, hence the term ELECTRICAL PRESSURE. This term is still used and represents the same condition as p.d. or e.m.f. Now potential, force, and pressure are not usually measured in the same units. It may seem strange that the volt, a unit of work per charge, can be used as a unit of force and a unit of pressure. Academically speaking, the volt is not the proper unit for force or pressure, but to the practical man, since p.d., e.m.f., and electrical pressure all represent the same set of conditions, the same unit will suffice.

Similarly, the pound is a unit of force and not a unit of pressure, but it is common to speak of so many pounds pressure in automobile tires. Also, the foot and the millimeter are both units of length or distance and not pressure, but such expressions as "a pressure of 30 feet", meaning the pressure resulting from water dammed up 30 feet high, or a "pressure of 730 millimeters", meaning the pressure required to support a column of mercury 730 mm. high, are frequently heard. The symbol usually used to represent a voltage, p.d., e.m.f., or electrical pressure is E. V is also used as a symbol for the volt.

ELECTRIC CURRENT - An electric current is said to flow when the free electrons drift or move along a conductor. Electric current is a direct result of an e.m.f. and will continue to flow as long as the e.m.f. exists. The rate at which the electrons pass a given section of the conductor is a measure of the current's magnitude, and is ONE when one unit of quantity passes in one unit of time, that is, a coulomb per second.

This unit of current is called the AMPERE and can also be defined as the current that is flowing when 6.28 times 10^{18} electrons are passing a point each second. As was stated before, the charge from 6.28 times 10^{18} electrons represents the quantity of electrical charge in a practical coulomb. The symbol that is usually used to represent electric current is I. A is also used as a symbol for the ampere.

DIRECTION OF CURRENT FLOW - The free electrons which constitute an electric current, flow from points of different potentials; that is, the free electrons are pulled or attracted toward the positive potential. In general, this would be from negative to positive, although it could be from positive to a greater positive or from a negative to a lesser negative value. In the early days of electricity, before anything was known of the electron theory, and electric current was considered to be the flow of some mythical fluid, naturally it was thought that the current would flow from a higher to a lower potential similar to the way water flows in a pipe connecting two reservoirs which are at different levels. Certain rules were developed on this assumption, and even after the electron theory was developed authors were hesitant in changing the rules. Only in recent years have certain authors of radio texts developed new rules or changed the old ones as to the actual

flow of current. The rules that need to be changed are very few and the changes very simple. The reason for changing the rules is that difficulty is encountered in presenting the vacuum tube theory from any other viewpoint then the electron flow. On the other hand, in connection with ordinary electrical phenomena the direction makes no difference. Exactly the same result will be obtained by either the old or the new conception of current flow. Nevertheless, it is important for the student to understand the essence of the above discussion in order that no confusion will result from the use of either method of presenting the direction of current flow.

RESISTANCE - When an electric current flows through a conductor, the motion is relatively a slow drift, probably only a few inches per second. The slowness of the electron movement is due to the fact that the free electrons which constitute the current are constantly colliding with other electrons, protons, atoms, molecules, or the nuclei of atoms, consequently retarding their progressive motion toward a point of higher potential. On the other hand, it must not be thought that the actual velocity of individual electrons is low. If it were not for the constant collisions mentioned above, the electrons would actually reach velocities many, many times as great, and the magnitude of the current would be limited only by the time the e.m.f. was applied. This condition need not be considered, as collisions take place in all conductors. Not only do these collisions retard the motion but set a limit to the magnitude of current (number of amperes) that will flow under a certain set of conditions. This opposition to the flow of current is called RESISTANCE, one of the important electrical properties of matter.

The unit of resistance is the ohm. The value of the ohm may be defined in several ways. The ohm is that amount of resistance which will limit the current to 1 ampere when 1 volt is applied. In other words, 1 volt of e.m.f. can force 1 ampere of current through 1 ohm of resistance. R is the symbol usually used to represent resistance. Ω is used as a symbol for ohm.

The laws of resistance were first investigated by Ohm, who showed that the resistance of a given conductor varies directly as its length and inversely as the area of its cross section. He also showed that it depends upon the material of which the conductor is composed. This can be stated as follows: $R = \frac{KL}{S}$ where L is the length, S the area of the cross section, and K is a constant depending for its value on the material. In other words, for a given material and at a fixed temperature, doubling the length causes the resistance to be twice as much, or doubling the cross-sectional area causes the resistance to be just one-half what it was before.

The resistance of all substances changes as their temperatures vary. The resistance of all metals increases as their temperatures rise; on the other hand, the resistance of most liquid and nonmetallic conductors decreases with an increase of temperature. The amount of change in resistance per ohm per degree is called the TEMPERATURE COEFFICIENT.

Ability to prepare standards of resistance which should be independent of temperature is highly desirable. Certain alloys have practically a zero temperature coefficient, and are suitable for use in measuring instruments and where it is important that the value of resistance remains constant as the temperature changes.

CONDUCTANCE - Conductance is an electrical property of matter and is the reciprocal of resistance. The unit of conductance is the MHO, and the symbol is G. The relation of conductance and resistance can be expressed as follows:

$$G = \frac{1}{R} \text{ or } R = \frac{1}{G}$$

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

SECTION II

MAGNETS AND MAGNETISM

MAGNETS AND MAGNETISM - These play an important part in the operation of many electrical devices and machines. Any object that has the ability to attract iron or steel is called a Magnet. The ability of this body to attract such objects is called Magnetism.

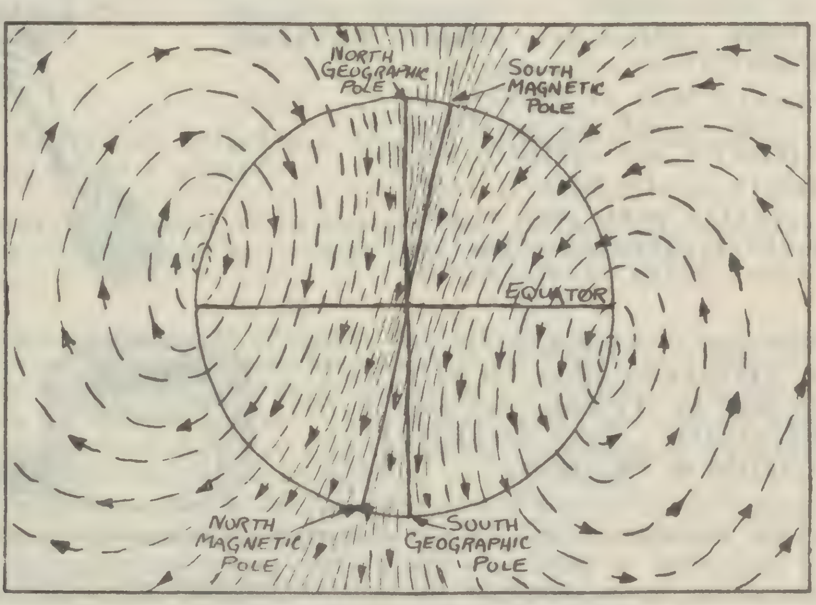
Magnets are used in many forms, such as magnetic tack hammers or toy horseshoe magnets to demonstrate their power to attract tacks, nails, and other iron and steel objects.

NATURAL MAGNETS - These were first found in Magnesia, a country in Asia Minor, about 600 B.C., and for this reason were called magnetite or magnets.

The first magnets were lumps of iron ore or oxide, which were found to have the power of attracting small pieces of iron. Later it was discovered that if an oblong piece of this material was suspended by a thread, it would always turn to a position with its length north and south. If moved or turned, the same end would always go back to point north. Thus, the end which pointed north was called the North-seeking or North end, and the other end was called the South-seeking or South end. It was used in this manner as a crude compass and often called "lodestone", meaning leading stone.

Compasses today are simply small steel needles that have been permanently and strongly magnetized, and mounted on jeweled pivots so they are free to turn easily.

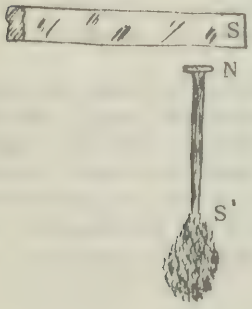
EARTH'S MAGNETISM - The earth is a natural magnet on a huge scale, with centers of magnetic force or attraction on its north and south sides. This is shown in the following illustration.



DIRECTION OF MAGNETIC FIELD
ABOUT THE EARTH

The magnetic attraction of the earth is the reason for the attraction of the ends of the compass needle to a north and south position. However, a compass does

not point exactly true north or south, because the earth's magnetic centers are not exactly at its true north and south geographical poles, or ends of its axis. In using a compass for accurate work, mariners, aviators, and surveyors allow a certain number of degrees for correction of this error, at various places on the earth. Note in illustration on preceding page, that the earth's magnetic poles are opposite to its geographical poles.



LOCATION OF POLES OF MAGNET

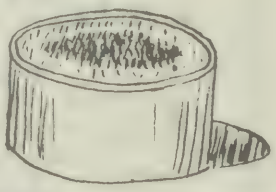
ARTIFICIAL MAGNETS - These are made of steel and iron, in various forms and can be made by properly stroking a bar of steel with a lodestone or some other magnet, or by passing electric current through a coil around the bar. A piece of iron often becomes magnetized, just lying near a strong magnet. This method is called Induced Magnetism.

EXAMPLE OF INDUCED MAGNETISM

If a small bar of soft iron, or nail, is held near to, but not touching a strong magnet, as in the illustration shown on the left, the small bar will be found to have magnetism also, and attract iron filings or other small iron objects. As soon as it is moved away from the permanent magnet, the small bar of iron or nail will lose its charge. This is an example of induced magnetism.

MAGNET POLES - All magnets whether natural or artificial, usually have their strongest pull or effects at their ends. These ends or points of stronger attraction are called Poles. Ordinary magnets usually have at least two poles, called *north* and *south*, because of their attraction for the north and south poles of the earth.

If a bar magnet is dipped in a pile of iron filings or tacks, it will attract them most at its ends, and not much in the middle. This is shown in the illustration on the right.



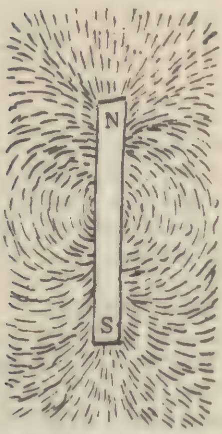
ATTRACTION AND REPULSION - If two magnets are suspended so they can turn freely until they come to rest with their north poles pointing north, and south poles pointing south, it is said that the ends which point north are alike, and the ends which point south are alike.

Now, if the poles of these magnets are marked and the two north poles are brougbt together, these like poles will tend to repel each other. But, if a north pole of one magnet is placed near a south pole of the other they will try to come together or attract each other.

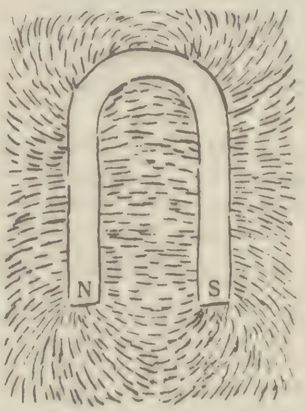
This proves one of the most important principles or rules of magnetism often called the first law of magnetism, as follows: *Like Poles Repel and Unlike Poles Attract.* This law should be remembered as it is the basis of operation of many electrical machines and devices.

LINES OF FORCE - Magnets do not have to be touching each other to exert their forces, they will exert their force of attraction or repulsion through a distance of several inches of air.

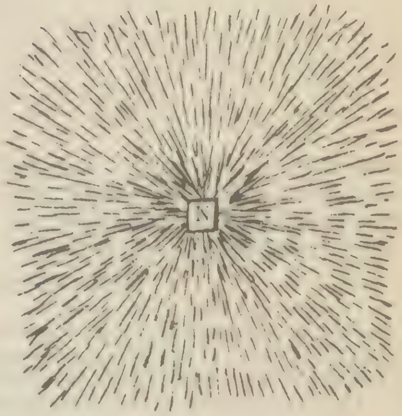
If we place a magnet under a piece of glass or paper which is covered with iron filings, and tap or jar it, the filings will arrange themselves as shown in the following diagrams:



MAGNETIC FIELD OF BAR MAGNET



MAGNETIC FIELD OF HORSESHOE MAGNET



ARRANGEMENT OF LINES OF FORCE ABOUT END OF BAR MAGNET

These illustrations afford some idea of the shape and direction of the lines of force acting around a magnet.

For practical purposes it is assumed that all magnets have what are called *Lines of Force* acting around and through them, and in the direction indicated in the diagrams above.

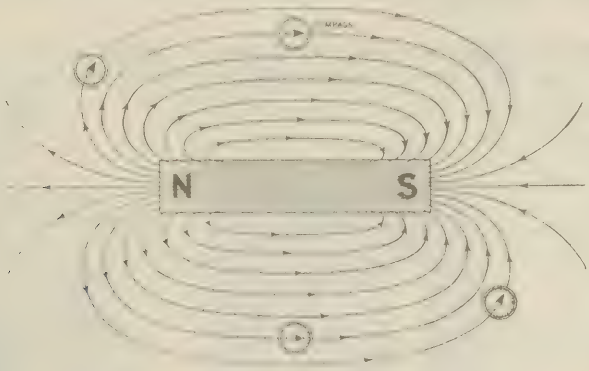
These magnetic lines are of course invisible to the eye, and cannot be felt. That the force is there can easily be proven by its effect on a compass needle. By moving a small compass around a large magnet we can determine the direction of the lines of force at various points. They always travel through the compass needle from its south to north pole, so it will always turn to such a position that its north pole indicates the direction the lines are traveling. It is well to remember this, as a compass can often be used to determine the direction of magnetic lines of force in testing various electrical machines.

MAGNETIC FIELD AND CIRCUIT - The lines of force around a magnet are called *Magnetic Flux*, and the area they occupy is called the *Field* of the magnet.

The strong, useful field of an ordinary magnet may extend from a few inches to several feet around it. With sensitive instruments this field can be found at great

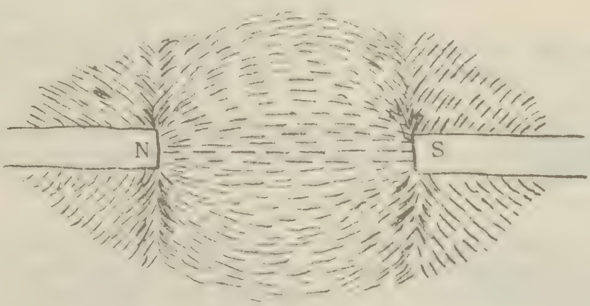
distances, almost infinitely, however it becomes rapidly weaker as the distance from the magnet is increased.

In the diagram below note that the lines of force through the bar or *Internal* path, are from the south to the north pole, and outside the magnet through the



THE MAGNETIC FIELD AROUND A BAR MAGNET

External path, are from the north to south pole. This is very important. The path of lines of force around and through a magnet is often called the *Magnetic Circuit*. When two magnets are placed with unlike poles near each other as in the following figure, their lines of force combine in one common path through both as shown by the dotted lines.



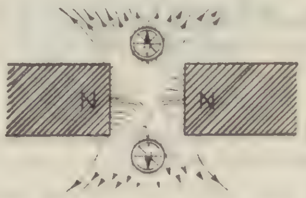
ARRANGEMENT OF LINES OF FORCE
ABOUT THE TWO DISSIMILAR POLES
OF TWO BAR MAGNETS

These lines tend to shorten their path still more by drawing the magnets together, thus their attraction for each other.

It may be well to consider magnetic lines of force as similar in some ways to stretched rubber bands, revolving like endless belts, and continually trying to

contract or shorten themselves.

This will help to establish a practical understanding of many important effects and principles of magnetism, without going into lengthy and detailed theory.



MAGNETIC FIELD
BETWEEN LIKE POLES

If we place two magnets with their like poles near each other as in the above illustration, we find their fields will not join, as the lines of force are coming in opposite directions. Therefore they crowd apart in separate paths between the ends of the poles, and the magnets push apart or repel each other to avoid this conflict or crowding of the opposing fields.

MAGNETIC AND NON-MAGNETIC MATERIALS - Experiments with magnets will show that only certain materials can be magnetized or attracted by magnets, while others cannot.

Those that can be magnetized we call magnetic materials. Iron and steel are good magnetic materials, and most magnets are made from them. Nickle and cobalt are somewhat magnetic.

Those that cannot be magnetized we call Non-Magnetic materials. Brass, copper, gold, silver, lead, wood, glass, air, etc., are all non-magnetic materials.

Soft iron is very easily magnetized, but does not hold its charge long. In fact it loses most of its magnetism as soon as the magnetizing force is removed.

Hard steel is much more difficult to magnetize, but when once charged it holds its magnetism much longer.

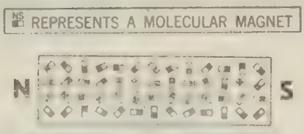
A good steel magnet may hold a strong charge for many years. Such magnets are called *Permanent Magnets*.

Materials that hold a charge well are said to have high *Retentivity*, meaning retaining power.

Therefore steel has high retentivity and soft iron is low in retentivity. In order to understand how magnets become charged, and why some will hold a charge better than others, it is necessary to briefly consider the molecular theory of magnetism. All matter is made up of very small particles called molecules, and these molecules consist of atoms and electrons.

Each molecule has a polarity of its own, or might be considered as a tiny magnet. In a bar of iron or steel that is not magnetized, it seems that these molecules arrange themselves in little groups with their unlike poles together, forming

little closed magnetic circuits as in the following illustration.



This illustration shows the molecules many times larger in proportion to the bar, than they really are.

Now, when lines of force are passed through the bar, from some other strong magnet, causing it to become magnetized, the little molecules seem to line up with this flux, so their north poles all point one way and all south poles the other way. This is illustrated in the following diagram:

In soft iron this change is effected very easily, and as already stated, it can be easily magnetized. But the molecules of iron also shift back to their natural position easily, so it quickly loses its magnetism.

With hard steel the molecules do not shift easily, it is harder to magnetize hard steel, but once charged, the molecules do not shift back to their normal position so easily, and it holds its magnetism much better.

When charging or making permanent steel magnets, tapping or vibrating the bar slightly seems to help speed the process. On the other hand, if a permanent magnet that has been charged, is struck or bumped about roughly it will lose much of its strength, as the jarring seems to shift the molecules. Therefore, permanent magnets should be handled carefully. (All D.C. meters have permanent magnets).

The magnetism of a bar can also be destroyed by heating it to a cherry red. This is called *De-Magnetizing*.

If a magnet is placed in a reversing flux or field from some source, so its charge or polarity is rapidly reversed, the rapid shifting of the molecules sets up heat. This is called *Hysteresis* loss. Naturally this effect is much less noticeable in soft iron than in hard steel, as the molecules shift easier and with less friction and heat, in the soft iron.

PERMEABILITY AND RELUCTANCE - Experiments prove that magnetic lines of force will pass through iron and steel, or magnetic materials much easier than through air, wood and brass, or non-magnetic materials of any kind. So iron and steel form a good path for magnetic flux, and are said to have high *Permeability*, and low *Reluctance*. The term reluctance is to magnetic flux what resistance is to an electric circuit.

If we place a small bar of soft iron in a field of a larger magnet, the lines of force will largely choose the easier path through the iron. This can be proven by sprinkling iron filings on a glass over such a group of magnets and iron. This not only proves that iron is of lower reluctance than air, but also that magnetic flux will choose the easiest path available.

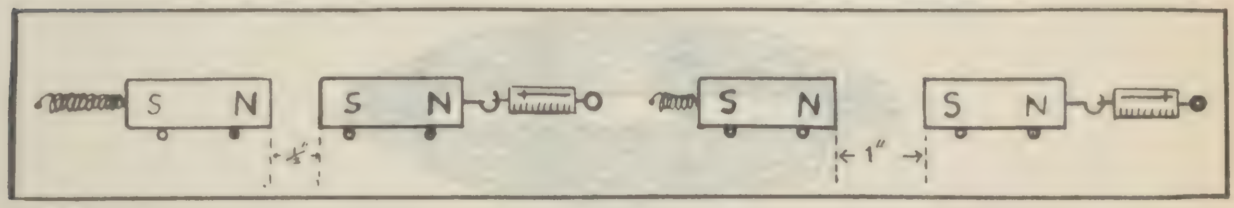
Good soft iron has only about 1/1500 part as high reluctance as air. For this reason we construct many magnets in the form of a horseshoe, which brings the poles closer together, greatly reducing the air gap reluctance and increasing the strength and life of the magnet.

A soft iron "keeper" is frequently placed across the ends of a horseshoe magnet when they are not in use, to provide complete closed circuit of magnetic material and eliminate the air gap reluctance. This will greatly increase the life of the magnet.

Horseshoe shaped magnets having unlike poles near each other, have a much greater lifting power when in contact with an iron surface, than only one end of a bar magnet. This is because the horseshoe type has a much better complete path of low reluctance for its lines of force, and the field will be much more dense, and stronger.

A good horseshoe magnet weighing one pound, should lift about 25 pounds of soft iron.

EFFECTS OF AIR GAPS - Since air is of such high reluctance, it is very important to reduce the air gaps as much as possible in all magnetic circuits to obtain the greatest possible strength of flux or pull.

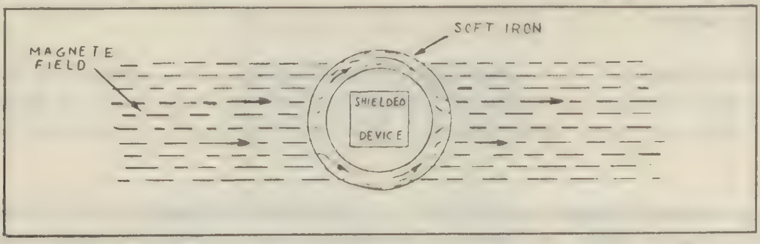


If two magnets are placed as in the above illustration and their pull measured, and then moved farther apart, the small increase in the distance is doubled, the pull is decreased to about one fourth of what it was. If the distance is tripled, the pull decreases to about 1/9 of the original value. If the distance is reduced to one half of the original amount the pull will increase to 4 times the original pull.

The above describes another very important law of magnetism, namely: The *force* exerted between two magnets varies *inversely* with the *square* of the distance between them. If the strength of the magnets is changed their combined pull will vary with the *Product of Their Separate Strengths*.

MAGNETIC SHIELDS - While iron is a good conductor of magnetic flux, and air is a very poor one, there is no known material that will insulate or stop magnetic lines of force. They will pass through any material. But we can shield magnetic flux from certain spaces or objects, by leading it around through an easier path. As previously mentioned, the lines of force will largely choose the easiest path. So if a shield of iron is arranged around a device as in the following figure, the flux can distort around and prevent most of it from entering the shielded area.

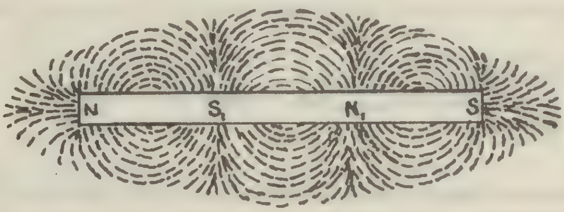
Quite often the magnetic field of some large generator or electric machine may affect the operation of a meter or some delicate device located near it. It is



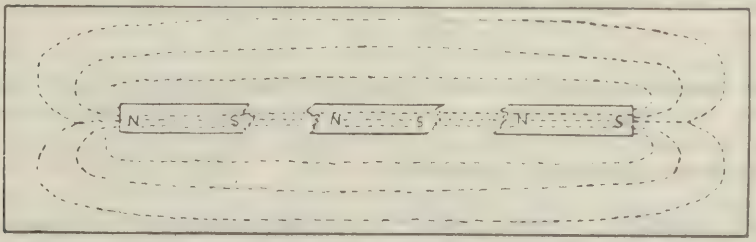
IRON SHIELD TO DEFLECT LINES OF FORCE AWAY FROM INSTRUMENT OR DEVICE

vital to remember how to shield such instruments. Many meters are equipped with iron cases to shield their working parts in this manner.

Occasionally in working with magnets, evidence of more than two poles, or points of attraction at other places along the magnet besides at its main poles may be observed. As the main poles are named Salient Poles, the other points of attraction are called Consequent Poles and are formed by adjoining sections being oppositely magnetized so the fluxes oppose. Very weak magnets may sometimes develop consequent poles. This is illustrated in the following diagram:



If a long magnetized bar is broken into several pieces, each piece will take on separate north and south poles. Refer to the following diagram:



BAR MAGNET BROKEN INTO SEVERAL PIECES. NOTE EACH PIECE TAKES ON SEPARATE POLES IN THIS CASE.

Two or more separate magnets with their like poles grouped together will in many cases give more strength than a single magnet the size of the group. Such a

magnet is called a *Compound Magnet*. A laminated iron core such as used in transformer construction is a good example of a compound magnet.

SPECIAL MAGNETIC ALLOYS - There are certain patented alloys of iron and steel mixed with other metals, which have very good magnetic properties. Some of these have higher retentivity than hard steel.

Cobalt Steel is one of these improved alloys, especially good for strong, permanent magnets.

Permalloy is another, of very low reluctance, used in thin ribbon form for wrapping telephone and telegraph cables.

A few materials show slight properties of repulsion to either pole of a magnet. Such materials are called *Diamagnetic*.

SECTION III

OHM'S LAW - D.C. CIRCUITS

GENERAL - Ohm's law is a simple, yet important law of electricity, named after George Ohm who discovered the definite relation between pressure, current and resistance in electrical circuits, and put it in the form of a simple statement or rule.

THREE FACTORS NECESSARY FOR CURRENT FLOW - In every electrical circuit, the following three factors are always present; Pressure, Current and Resistance.

All circuits have some resistance; therefore, to cause current to flow, Pressure, or electro-motive force (e.m.f.) must be present.

OHM'S LAW IN D.C. CIRCUITS - The current in any D.C. circuit is always directly proportional to the pressure, and inversely proportional to the resistance.

Assuming the resistance remains constant, if we increase or decrease the voltage (pressure) applied, the current will increase or decrease in the same amount.

For example, if 110 volts force 10 amperes through the resistance of a certain circuit, 220 volts will force 20 amperes thru the same resistance, 55 volts will force 5 amperes, etc.

If the resistance of a circuit is increased, the voltage kept constant, the current flow will be decreased. If the resistance of a circuit is decreased, the voltage kept constant, the current flow will increase. This relationship is identified by the expression, "inversely proportional".

For example, assume a current of 10 amperes flows thru a circuit of 30 ohms resistance, if the resistance is changed to one of 60 ohms then only 5 amperes of current will flow. If we change the resistance to 15 ohms, 20 amperes will flow.

OHM'S LAW FORMULAS:

$$I = \frac{E}{R} \qquad E = I \times R \qquad R = \frac{E}{I}$$

In which:

I = Current in amperes.
E = Pressure in Volts.
R = Resistance in ohms.

For example, a ten volt battery is supplying current to a 5 ohm lamp. How much current will flow? Using the first formula, $I = \frac{E}{R}$ and substituting the known factors in this formula $I = \frac{10}{5}$ or 2 amperes.

Assume that a certain electric heater has a resistance of 10 ohms and requires 12 amperes to operate it, what voltage should this device be operated on? This can be determined by the second formula, $E = I \times R$, or $E = 12 \times 10$ or 120 volts.

Assume an electric oven is operating and its resistance is known to be 2 ohms. An ammeter in the circuit shows that a current of 55 amperes is flowing, what voltage is being applied? Using the second formula $E = I \times R$, $E = 55 \times 2$ or 110 volts.

A voltmeter in the circuit of an electro-magnet shows 80 volts applied to it. An ammeter shows 20 amperes flowing. How can the resistance of the magnetic coils be determined? Using the third formula, $R = \frac{E}{I}$ or $R = \frac{80}{20}$ or 4 ohms resistance.

SIMPLIFIED OHM'S LAW FORMULA - A very simple way to remember all three of

these formulas in one, is shown in the following: $\frac{E}{I x R}$

To determine the unknown factor simply cover the one unknown and the remaining two factors show what must be done to establish the unknown value.

For example, the current and resistance of a circuit is known, to find the voltage, cover E and the parts still showing indicate that I must be multiplied by R. If the voltage and resistance is known, to find the current, cover I and, as indicated by the remaining two factors, divide E by R.

WATT'S LAW - The watt is the unit of electric power. To produce power, a current must flow under pressure. One ampere flowing under a pressure of one volt will produce one watt of power.

The formulas for Watt's Law are as follows: $I \times E = W$, $W \div E = I$, $W \div I = E$.

In which:

$I =$ Current in amperes.
$E =$ Pressure in volts.
$W =$ Power in watts.

There are also other convenient formulas for finding the power in watts, when the amperage and voltage is not known, but the amperes and ohms resistance of the circuits or device is known, or the volts and ohms of the circuit or device isknown. They are as follows:

$I^2 \times R = W$ $\qquad$ $E^2 \div R = W$

In which:

I^2 equals amperes squared, or multiplied by itself.
E^2 equals volts squared, or multiplied by itself.
R equals resistance in ohms.

LINE DROP - The term line drop refers to voltage used or required to force the current through the line resistance alone. This is an important item to consider on long line runs, or feeders of considerable length to transformers, etc. If the voltage drop in the line is too great, there will not be sufficient voltage (pressure) at the end of the line to operate the device.

LINE LOSS - This term refers to power consumed by the line, and which goes into heat along the line. It is usually expressed in Watts. Line loss is determined by using Watt's Law formulas. Simply multiply the current in the circuit by the voltage drop in the line.

For example, a generator produces 130 volts pressure and sends 5 amperes of current over a line with 4 ohms resistance, to a lamp which requires 5 amperes at 110 volts to operate it. There is a 50 volt line drop in this circuit. Therefore, the line loss is $I \times E_d = W$ or $5 \times 20 = 100$ Watts.

In which:

I equals amperage.
E_d equals voltage drop.
W equals Watts lost.

SECTION IV

SERIES AND PARALLEL CIRCUITS

SERIES AND PARALLEL CIRCUITS

According to the electron theory, the flow of electricity is controlled by the action of free electrons. The flow of electricity is frequently compared to the flow of water. There are instances, however, when the flow of water is just the opposite of that of electricity. For example, consider an oil drum standing on end and filled with water. If a hole were to be made in the side of the oil drum, water would pour out of the side of the drum until the water level reached the hole. Electricity or electric current will not run out of the end of a wire, because air effectively is an insulator, and as such repels electricity. Similarly, a cork would stop the flow of the water from running out of the barrel. Since electricity will not flow out of the end of a wire, a complete circuit must be made to have a flow of electrical current through the wires.

An electrical circuit is that path or route taken by an electric current through conductors, (wires), or apparatus from point to point, until it again returns to its starting point. This is known as a closed circuit.

A completed or closed circuit is not all that is necessary to have a flow of current through conductors, (wires), or apparatus.

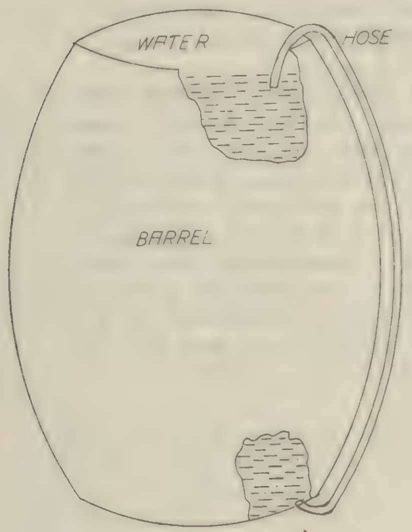


ILLUSTRATION NO. 1

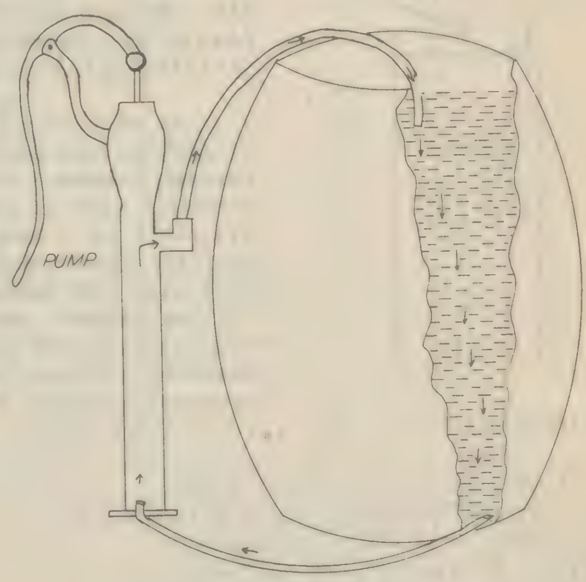


ILLUSTRATION NO. 2

In the above Illustration No. 1, a barrel of water is shown with a hose attached from an outlet in its base, to the water in the barrel. This is similar to an electrical closed circuit, yet no water will flow. If a common hand pump were to be installed into the hose as shown in Illustration No. 2, every time the handle of the pump is operated, water would flow through the circuit. This proves we must have in addition to the closed circuit a means of providing pressure. Illustration No. 3 shows a dry cell providing the electrical pressure necessary to allow the free electrons to flow in the closed circuit, represented by the cell, wires and lamp. As shown by the arrows in Illustration No. 2, the water will flow every time the pump handle is operated downward, due to the piston and valve in the pump. Similarly, the electrical flow shown by the arrows in Illustration No. 3 is set in motion by the chemical action of the dry cell. The flow of current is from the positive (+) terminal to the negative (—) terminal in the external (outside of the cell) circuit.

Many devices such as lamps, bell buzzers, etc., can be connected in a circuit to cause the current to flow in either direction through the device itself. No change will be noted when such a reversal of direction of current flow is made. On the other hand, if polarized devices such as meters are employed in the circuit, care must be exercised to make certain the meters are connected to the proper polarity of the voltage source. Most polarized devices will indicate upon its terminal studs or binding posts, the sign +, or POS, meaning that terminal of the device is to be connected to the positive side of the circuit. Some devices may only have a stud or binding post marked, minus, or negative, meaning that terminal is to be connected to the negative side of the circuit. The reversal of the wires leading to a meter of the polarized type, for example, will result in the meter pointer attempting to read downscale, thus the needle will strike the pointer stop inside the meter case. This can cause the meter pointer to become bent, and can even cause the pointer to snap off. Devices that do not have markings on its terminal rarely are polarized, and will therefore, operate satisfactorily in either direction.

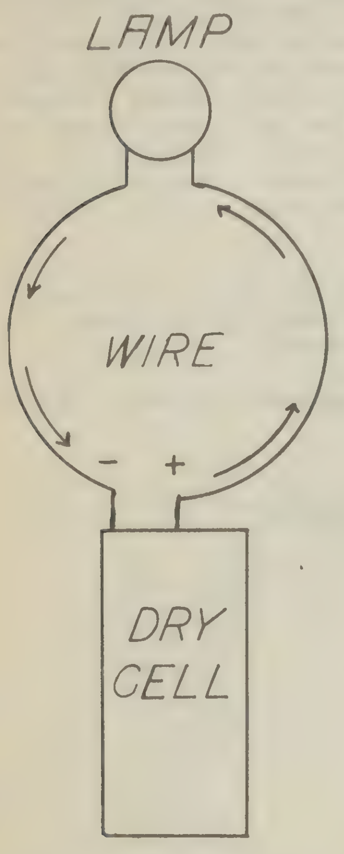


ILLUSTRATION NO. 3

As stated, it is essential to visualize the flow of electricity as being similar to the flow of water through a pipe. Water will always flow from the high pressure side to the low pressure side. This is also true of the flow of an electric current. As the positive (+) terminal of a dry cell, storage battery or generator, is generally considered the terminal that has the highest pressure, the flow of electric current will be from the positive (+) terminal of the voltage source, through the conductors and devices of the external circuit, back to the negative (—) terminal of the voltage source.

Illustration No. 4 shows a very simple circuit employing a dry cell, push button, bell and interconnecting wire. It can be seen that whenever the push button is closed, a completed circuit, from one side of the cell through the bell, through the push button, to the other side of the cell will result. As the flow of current is from the positive (+) terminal, to the negative (—) terminal of the cell, the current flow will take the direction indicated by the arrows. As long as the push button is closed, and the cell provides voltage, the bell will ring. When the push button is released, an "open circuit" will result, and the bell will no longer operate. The voltage of the cell is not great enough to overcome the resistance of

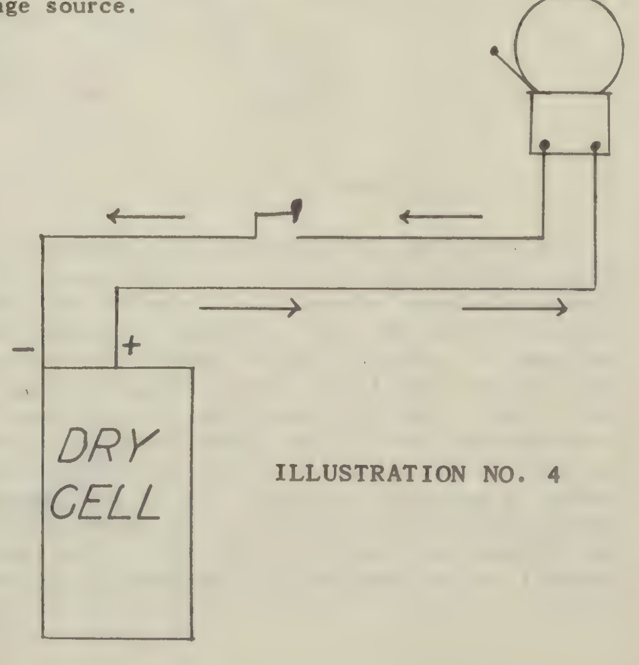
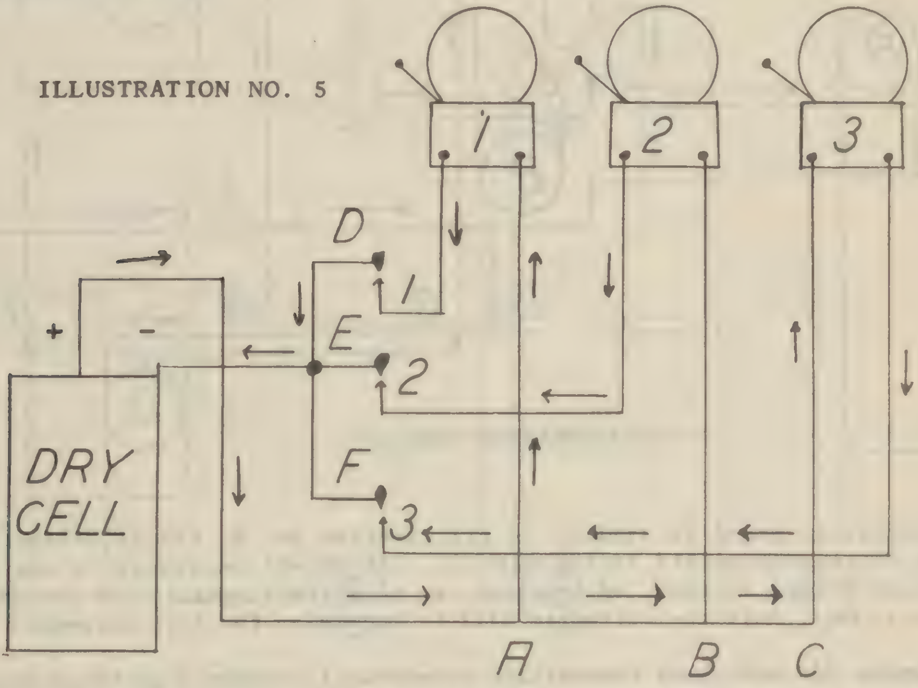


ILLUSTRATION NO. 4

the air between the two ends of the wires at the point of the break. The position that the push button occupies within the circuit is unimportant, as it will perform its function of controlling the ringing of the bell, no matter where it is placed within the circuit. The ringing of the bell can be stopped by breaking or causing an open circuit at any point within the circuit.

It must not be assumed that only one device can be energized from any one source of voltage. Illustration No. 5 indicates how three bells may be energized from one source of voltage.

ILLUSTRATION NO. 5



Tracing the flow of electric current as indicated by the arrows, it is readily apparent that there are three separate and distinct, simple circuits. It is not necessary to run separate wires from each circuit to the source of voltage. The wire from the negative terminal of the cell to the common wire connecting points D, E, and F, will act as the current carrying conductors for any or all of the separate circuits. The same holds true of the wire running from the positive (+) terminal of the cell to points A, B, and C.

By following the direction of current flow, as shown by the arrows, from the positive (+) terminal of the cell, through the bell, it can be ascertained that the push buttons 1, 2, and 3, will complete a circuit, whenever they are closed. It is also clear that any or all of the bells can be made to operate separately or simultaneously. For example, suppose push button #2 was closed. The flow of current would be from the positive terminal to point "B" through bell #2, through button #2, and return to the negative (—) terminal of the cell. The circuits for bells #1, and #3, will be open at the push button #1, and #3, because the voltage from the dry cell cannot overcome the resistance of the air between the ends of the wires located at these points. The placement of the push buttons can be made at any point within its own circuit. For example, push button #3 can be placed at any point between points "F" and "B", push button #1 can be placed at any point between "D" and "A".

Since a volt is a unit of electrical pressure, it must be rightfully assumed that a voltmeter is a device to measure or indicate the electrical pressure between any two points of a circuit.

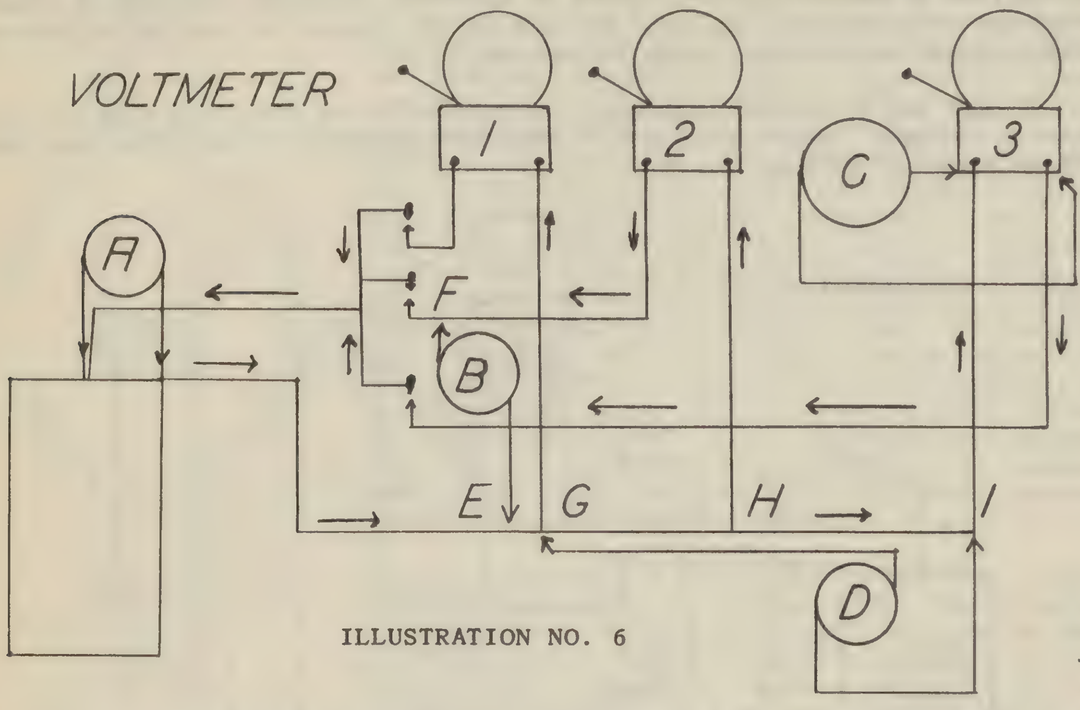


ILLUSTRATION NO. 6

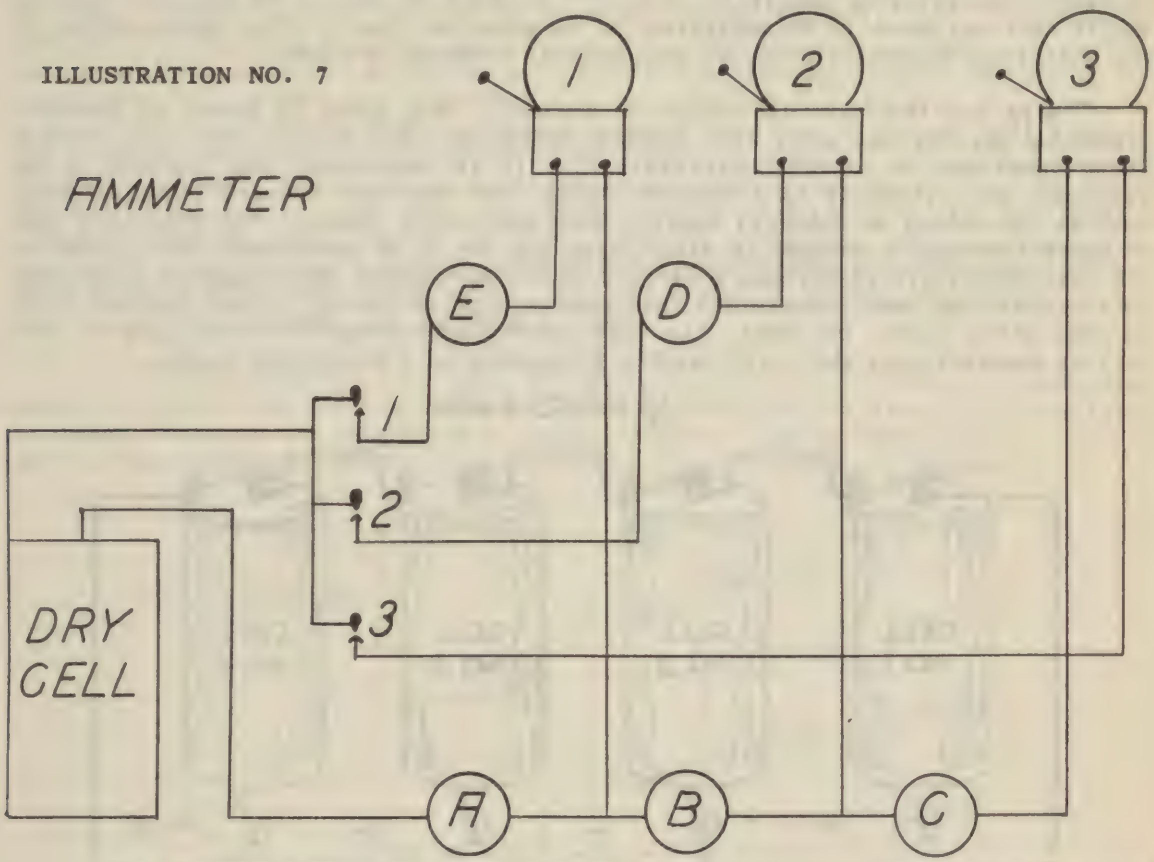
Illustration No. 6 is similar to Illustration No. 5, except voltmeters are now shown at various points in the circuit. It is not necessary to use as many voltmeters as shown, in fact, by touching the wire leads coming from the voltmeter at various points, only one voltmeter will be necessary for test purposes.

Voltmeter "A" will show the voltage (electrical pressure) of the dry cell itself. Voltmeter "B" will indicate the voltage between points E and F. Voltmeter "C", across bell #3 terminals, will show the voltage that is forcing the electric current through the bell #3. This meter "C" will read less than meter "A". This results because a certain amount of the dry cells voltage was used in forcing the electrical current from the positive (+) terminal through the bell and push button, back to the negative terminal of the dry cell. Some materials make much better conductors than others. On the other hand, *all* conductors offer some resistance to the flow of electric current, therefore, it will "use up" part of the voltage from the source of supply. Meter "D" shows how a voltmeter may be used to determine the amount of "voltage drop" across a length of wire, or a portion of a circuit. In Illustration No. 6, the meter is connected between points G and I, therefore, meter "C" will read the voltage "used up" (line drop), forcing the electric current between these two points.

An ammeter is an instrument that indicates the amount of amperes flowing through a circuit, similar to a flowmeter showing the amount of water going through a pipe. This instrument too, may be of a polarized type, which means the positive (+) terminal of the meter must be connected to the wire coming from the positive terminal of the source of voltage. Some ammeters can be inserted in either side of a circuit. A good rule to remember is, if an instrument has terminals unmarked, it can in all probability be connected in either side of a circuit. However, if any terminals

are marked either positive (+), or negative (—), anticipate that it is a polarized device and should be inserted in only one manner in the circuit.

ILLUSTRATION NO. 7



The above Illustration No. 7 shows the method of connecting an ammeter into various parts of a circuit. It can be seen that any amperage used in the circuit will register in ammeter "A". Ammeter "B" will show the current flowing to bells #2 and #3. Ammeter "C" will register the current to bell #3. Ammeter "D" shows the amount of current flowing to bell #2, and meter "E" indicates the current flowing to bell #1.

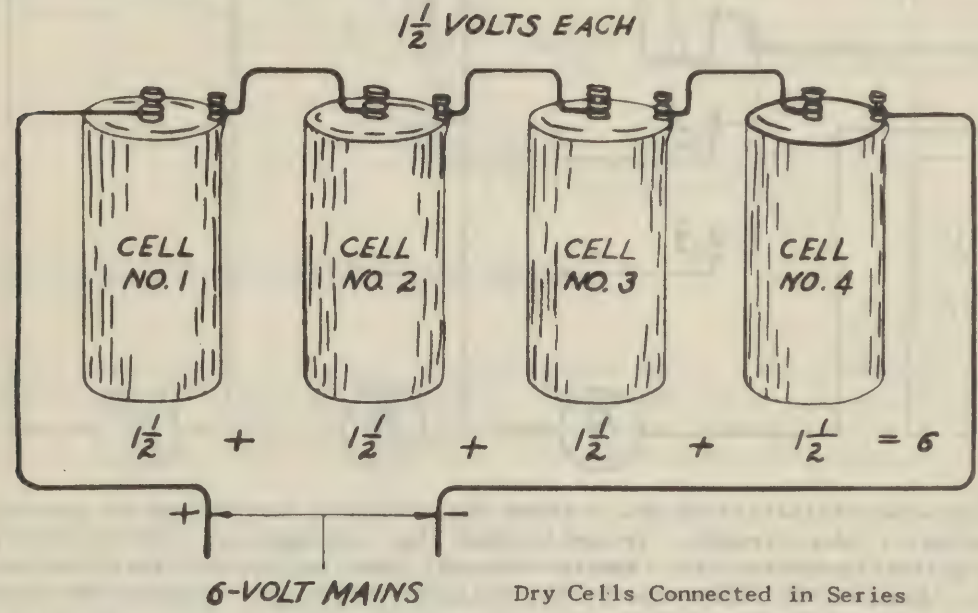
The use of 5 meters in the above diagram is used primarily for the purpose of illustration. In general, for test purposes only one or two ammeters will be used, and moved from point to point in the circuit.

Note the different manner in which a voltmeter and ammeter are used in a circuit. An ammeter is a low resistance device, and is always connected in series in a circuit. It is important to remember that an ammeter can be burned out if it is improperly connected to a circuit.

A voltmeter, being a device to indicate the pressure of a circuit, is always connected in parallel (connected across). A voltmeter is a high resistance device, its resistance may be so high, in fact, that if it were to be incorrectly connected into some circuits, these circuits would fail to operate. This would be due to the excessive resistance (in the meter proper), to the current in the circuit.

X-ray apparatus, in common with any similar types of devices employing electrical circuits, is generally made up of a series of main and auxiliary circuits hooked up either in series or parallel, or both. In order to locate the various types of faults that may occur in an apparatus, it is essential that a clear understanding of the difference between the series and parallel circuits be known.

There are two main divisions of devices. One group is known as current-producing devices and under this heading batteries, generators, etc., are listed. These names may be somewhat misleading for it is understood that current is not produced, but rather it is a form of energy that has been changed from one form, such as mechanical or chemical energy, into electrical energy. The technical name of current-consuming devices is also misleading for it is understood that current is not lost in its travel through a circuit, but that current which appears to be lost in a circuit has been transformed into another type of energy, either radiant heat, or some other form. No doubt, the term current-consuming device originated with various manufacturers who build devices to operate on a designated voltage.



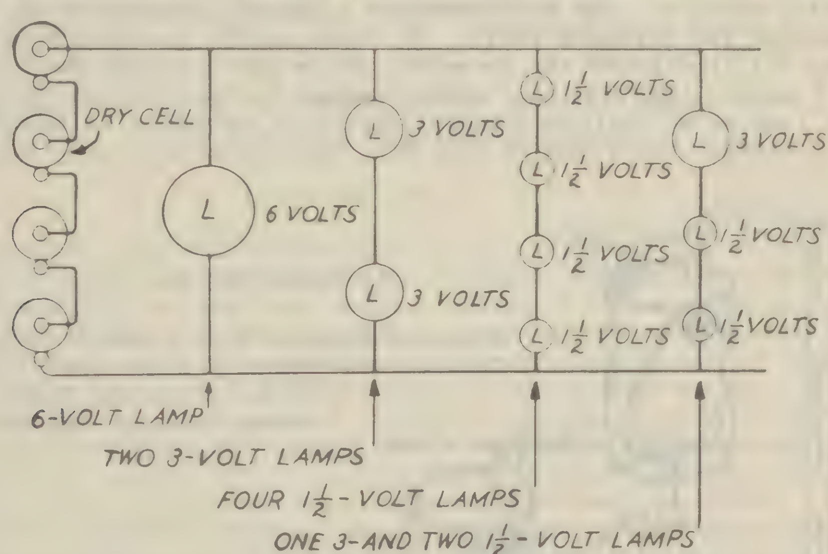
Dry Cells Connected in Series

ILLUSTRATION NO. 8

In the above Illustration No. 8 note that short wires are placed from the center or positive (+) terminal of one cell to the negative (—) terminal of the other cell. This grouping, utilizing four cells, makes up what is known as a battery arrangement. Two or more cells constitute a battery arrangement. If a voltmeter is placed across the remaining positive (+) and negative (—) terminals (making certain that a polarized voltmeter is connected to the proper terminals), a voltage reading of 6 volts will be obtained on the meter. Since each cell has 1½ volts, it will be immediately apparent that the voltages from each cell has added, and we have the advantage of an increased pressure from this battery arrangement. This rule holds true for any multiple of cells. If fifty cells were connected in SERIES (as shown), a total of 75 volts of pressure would be available. The capacity of each cell to produce and maintain current is so small that, in spite of having a considerably increased pressure, only the current-producing abilities of a single cell would be available.

With many cells connected in series, thus producing increased pressures, with the current capacity of only one cell, care must be exercised in determining that the device to be used from this type of power source has been designed for this type of power. Since there is no current flowing through the cell until the external circuit is connected from the positive (+) to the negative (—) side, it will be easily understood that any device employed in the external circuit which has low resistance will exhaust its batteries in a very short while. On the other hand, if a device of comparatively high resistance is used, very little current will flow and the battery arrangement could be then considered as a fairly efficient source of voltage or e.m.f. Ohm's Law is utilized by the various manufacturers who build electrical devices in order that a guide can easily be established for determining the best form of power supply for all electrical equipment. The law for series circuits is as follows: CURRENT THROUGH A SERIES CONNECTION IS THE SAME AS CURRENT THROUGH EACH INDIVIDUAL PART. VOLTAGE ACROSS A SERIES CONNECTION IS THE SUM OF VOLTAGES ACROSS ALL INDIVIDUAL PARTS.

If a small automobile type lamp, designed to operate on 6 volts, were connected across the main lines of these four cells, it would become energized. Various types of lamps designed for operation at voltages lower than 6 volts, can be made to operate with a hookup similar to that shown in Illustration No. 9, below.



Method of Connecting Lamps of Different Voltages So They Can Be Operated from the Same Set of Dry Cells

ILLUSTRATION NO. 9

The four dry cells are shown plus the various arrangements which will be necessary to use the lamps designed for various voltages less than 6 volts. In Illustration No. 9, it is shown that any number of devices designed to operate at a certain voltage, when applied in series, can be employed in a circuit which has a voltage equal to the total of the voltage of the device. For example, with the 6 volts obtained from the four dry cells we can use one 6-volt lamp, two 3-volt lamps, four 1½-volt lamps, or a 3-volt and two 1½-volt lamps without any danger of damage to the lamps. This fact can be described using a common device, such as a string of Christmas tree lights, arranged in series, that, when one bulb fails, the entire string of lamps go out. By replacing the defective bulb the entire string would again function. Regardless of the fact that this string of bulbs is energized from

the ordinary house voltage, 110 volts, since the entire string was connected in series, it is possible to utilize bulbs designed for voltages considerably below 110 volts. There are usually 10 lamps in a string, the truth of our previous conclusion is; the voltage across series combinations is the sum of the voltage across each separate part. Therefore, to determine the operating voltage of each lamp we would use the following formula:

$$110 \text{ volts} \div 10 \text{ bulbs} = 11 \text{ volts per bulb.}$$

Thus it is apparent that each bulb was designed to operate at 11 volts.

Frequently it is possible to group different types of devices for operation on circuits which have a higher voltage than the voltage indicated on the name plates of these devices as being the voltage with which the unit is designed to operate. This point is sometimes difficult to understand until the factor of resistance is considered. Assume that two bulbs, both designed to operate on 55 volts, are to be placed in one circuit, one requiring 1 ampere and the other requiring 2 amperes for operation. Connecting these two bulbs in series across 110 volt line, one finds that the bulb requiring 1 ampere will burn very brightly and the other lamp will burn rather dimly. This change of illumination can be explained by another law of series circuits which is, THE RESISTANCE OF A SERIES COMBINATION IS THE SUM OF RESISTANCE ACROSS THE SEPARATE PARTS. In other words, the reason the 1-ampere bulb lights up brilliantly and the 2-ampere bulb is not receiving its full voltage, is that the 1-ampere lamp will only allow 1 ampere to flow through the circuit and the 2-ampere lamp is not getting enough current to permit it to operate at full efficiency, therefore the 1-ampere lamp will receive an over supply of voltage.

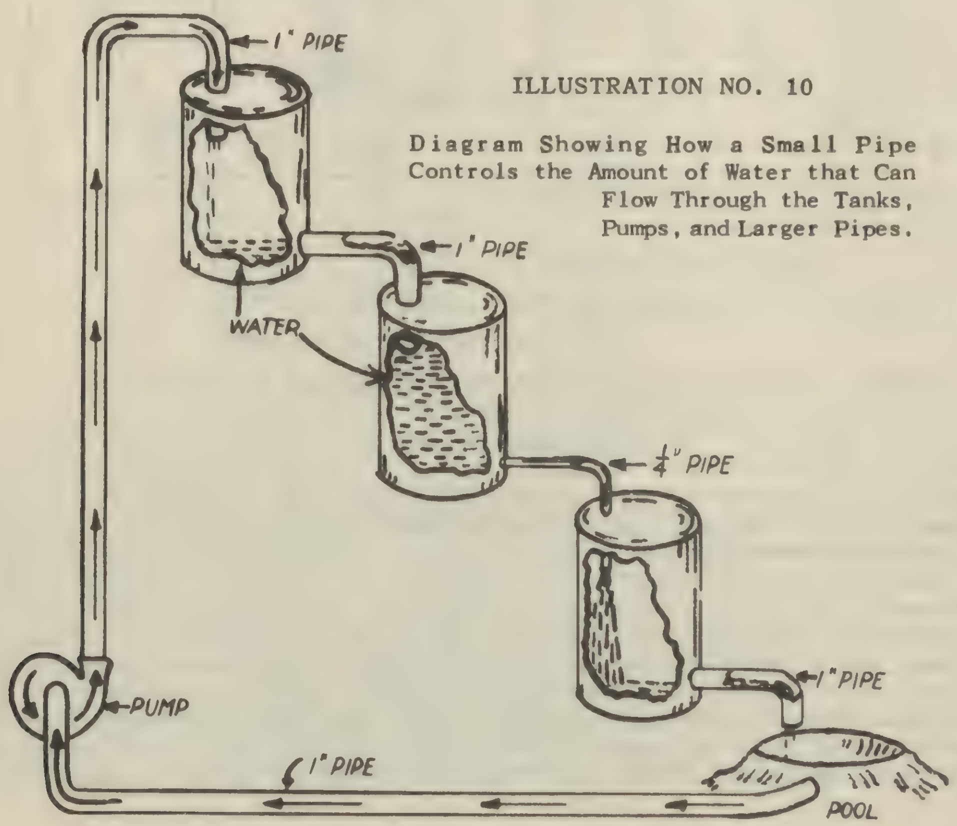


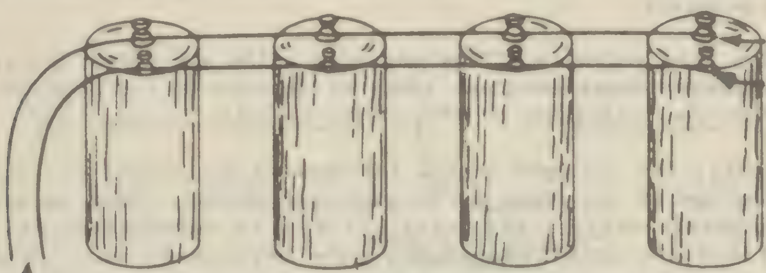
ILLUSTRATION NO. 10

Diagram Showing How a Small Pipe Controls the Amount of Water that Can Flow Through the Tanks, Pumps, and Larger Pipes.

Illustration No. 10 is shown to clarify the previous statement. The first and second tank are connected by 1-inch pipes and the second and third tanks are connected by ¼-inch pipe, and the third tank has a 1-inch pipe outlet. It is apparent that no more water can flow through this circuit than will flow through the ¼-inch pipe. Likewise, no more amperage can flow through a circuit than is allowed to flow by the highest resistance device in the series circuit.

Therefore, it can be said that no more amperage can flow through the circuit than that permitted by the highest resistance device in the complete circuit.

Four cells, connected as shown in the following Illustration No. 11, are described as four cells connected in parallel.



Four Dry Cells Connected in Parallel

ILLUSTRATION NO. 11

It is apparent that all of the positive (+) terminals are connected together and all of the negative (—) terminals are connected likewise. It can be determined by means of a voltmeter that the voltage obtained from this type of hookup is similar to that supplied by one cell alone, in this particular instance, 1½ volts. It is apparent that with such an arrangement the voltage obtained is similar to that obtained from one cell only. The advantage of this arrangement is that it permits the use of the capacity in amperes of the sum of all the cells in the parallel hookup. This is similar to an arrangement where four faucets are used to supply water to a large tub or vessel. It is obvious that the amount of water to the tub will be the total of the water received from the four faucets. Thus; THE CURRENT THROUGH PARALLEL COMBINATIONS IS THE SUM OF CURRENT THROUGH EACH BRANCH, and, inasmuch as a voltmeter will indicate that the voltage obtained is the same as obtained from one cell, it is stated that the VOLTAGE ACROSS PARALLEL COMBINATIONS IS THE SAME AS VOLTAGE ACROSS EACH BRANCH.

The above applies to devices under the current-producing classification. All devices used in parallel must be rated to operate on the voltage obtained from the source of voltage and the Illustration No. 12 shows the means of connecting a number of 110 volt lamps in parallel across the voltage supplied by a generator.

From Illustration No. 12 it is apparent that if one of the lamps should burn out, it would not affect the operation of the remaining lamps in the circuit. This arrangement is now used in the later type of Christmas tree lamps now in general use. In the event one lamp should burn out, the other lamps of the string will continue to burn. The main difference is, that these lamps are now connected in parallel across the 110 volts incoming house line and the lamps are designed to operate on 110 volts instead of the original type which was hooked in the series circuit and

Four Lamps Connected in Parallel
ILLUSTRATION NO. 12

operated on 11 volts. Another advantage of the parallel circuit is that it is not necessary to anticipate the resistance of the various devices connected in the circuit since each unit or device in this parallel circuit will only utilize that amount of current for which it was designed. Thus, a lamp drawing ¼ ampere and another drawing 1 ampere, a motor drawing 5 amperes, and a toaster drawing 7 amperes across the same 110 volt line of house current, will operate properly.

In series circuits, the voltages of the separate units are added to determine voltage necessary to operate these devices. The resistances of the separate units added together determine the resistance of the entire circuit.

In parallel circuits, the voltages across the devices are constant. The total current is equal to the sum of the currents through each device. When working with electrical apparatus, particularly x-ray units, it will be discovered that series and parallel connections are used throughout. The serviceman who can readily identify these two types of circuits and any variations or combinations of these two types of circuits, will find that this knowledge, plus reasoning power, will be of tremendous assistance in determining the function of the various parts of all electrical apparatus. A thorough application and familiarity of the rules established by Ohm's Law will enable a serviceman to improvise and utilize various materials foreign to x-ray apparatus or improvise various hookups to have the x-ray device operate in spite of the total failure of some component part of the apparatus itself. For example, visualize a surge resistor in the primary of a high tension circuit of any x-ray machine as having failed. It would be dangerous to the remainder of the apparatus to operate this machine at high kilovoltage without this surge resistor. If no other resistor of a similar resistance and carrying capacity is available, it is possible to use a bank of ordinary house lamps, or an electric toaster, or even construct a resistor from a supply of iron wire which might be available from packing cases, etc. The fundamental rules of series and parallel circuits in the application of Ohm's Law in most A.C. circuits and in all D.C. circuits will enable you to use a wide variety of material to have your x-ray apparatus operate under almost any conditions. X-ray apparatus of any type is nothing more than a variety of main and auxiliary circuits connected in series and parallel through various devices. Time and utilization of reasoning power plus the application of your knowledge of series and parallel circuits and Ohm's Law will enable one to keep any type of x-ray apparatus in operation.

The effects of resistance in series and parallel circuits differ, the following examples and explanations are given to make a clearer understanding possible. The use of *non-inductive* resistance in a circuit, will in most cases, allow the use of Ohm's Law to calculate the various factors of the circuit on either A.C. or D.C. current. The following examples and explanation will refer to this type resistance only. The various formulas to determine A.C. circuit factors when inductive resistance, capacity, etc. are employed are explained elsewhere in this text.

From the foregoing it is possible to determine the following: In a series circuit, the current is the same in all parts of the circuit, no matter what the resistance may be.

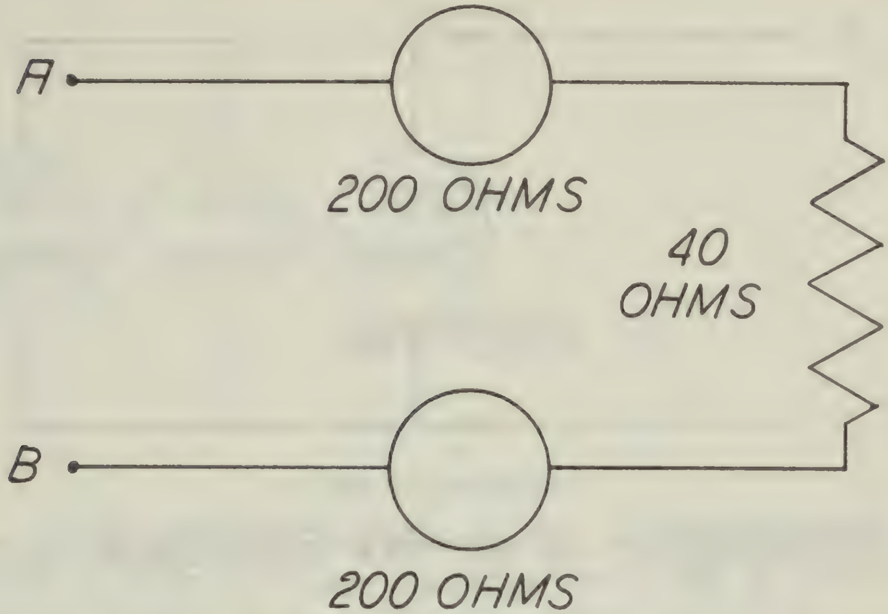


ILLUSTRATION NO. 13

In the above Illustration No. 13, two lamps of 200 Ohms resistance each and a resistor of 40 Ohms are in series with a line of 220 volts. To determine the resistance in this arrangement, $R = 200 + 200 + 40$ or 440 Ohms. Total circuit resistance from Ohm's Law: $I = \frac{E}{R}$ or $\frac{220}{440} = .5$ Ampere flowing through the circuit. This demonstrates the fact that the total resistance of a series circuit is the sum of the individual resistors.

In the above it can be determined that .5 ampere flows through all portions of the circuit. To determine the voltage (pressure) necessary to force the current through each part, using Ohm's Law. As $E = I \times R$ or Voltage = Amperes x Resistance.

200 Ohms x .5 amps = 100 Volts
200 Ohms x .5 amps = 100 Volts 2nd lamp
40 Ohms x .5 amps = 20 Volts for resistor
100 Volts plus 100 Volts plus 20 Volts equals 220 Volts incoming line.

From the example above it is possible to determine a third fact about series circuits:

The voltage across the source of a series circuit equals the sum of the voltage across the individual resistances.

The rules for parallel hookup of current-consuming devices in a circuit differs in many respects to those for the series hookups.

In Illustration No. 14 we have three non-inductive devices hooked across the incoming line of 120 Volts. It is apparent that all three devices are receiving the full 120 Volts pressure. Therefore the first fact can be established.

The voltage across the parallel combination is the same as the voltage across each branch.

The determination of the current flowing through the above circuit (which will register on the ammeter) is obtained using Ohm's Law.

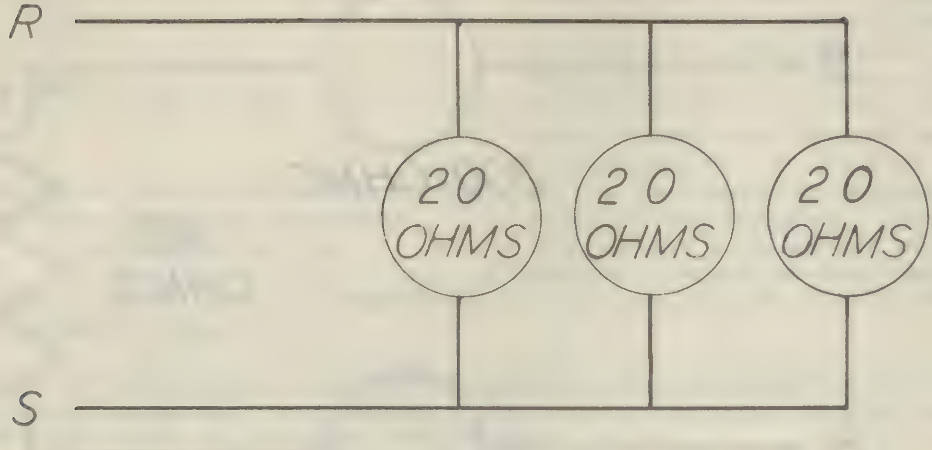


ILLUSTRATION NO. 14

Given a line of 120 volts, and 3 lamps with a resistance of 20 Ohms each, using Ohm's formula $I = \frac{E}{R}$, $\frac{120}{20} = 6$ amperes for one lamp. Since there are three lamps in the circuit, add the sums of the other two lamps to the first and the ammeter will read 18 amperes, when all three lamps are placed in the Circuit. Thus the conclusion with parallel circuits is:

The current flowing through a parallel combination is the sum of the currents in its separate branches.

In determining the resistance of a parallel circuit, using the 3 lamp Illustration No. 14, it may appear that if one lamp has a certain resistance, three similar lamps should have three times the resistance to the flow of voltage between the incoming line. However, the three paths of voltage (through the lamps) provide an easier path for the flow of current than only one lamp. Since one lamp has a resistance of 20 Ohms and the current through the circuit is 6 Amperes, then with three lamps in a parallel connection, a total of 18 Amperes is obtained through the combination of three lamps in parallel. (Ohm's Law). R (of combination) = $\frac{\text{E (across combination)}}{\text{I (thru combination)}}$ or $\frac{120}{18} = 6.666$ Ohms. The total resistance of this combination of the three 20 Ohm lamps across the 120 volt line is 6.666 Ohms. Therefore the procedure should be followed to establish the resistance of a parallel combination.

1st - Determine the current through each branch.
2nd - Add, to determine the total current through the combination.
3rd - Apply Ohm's Law $R = \frac{E}{I}$ to determine the resistance of the combination.

A thorough knowledge of the various functions of Ohm's Law as applied to series and parallel circuits is absolutely necessary. Some of the rules are in direct opposition to each other when used in the different types of circuits.

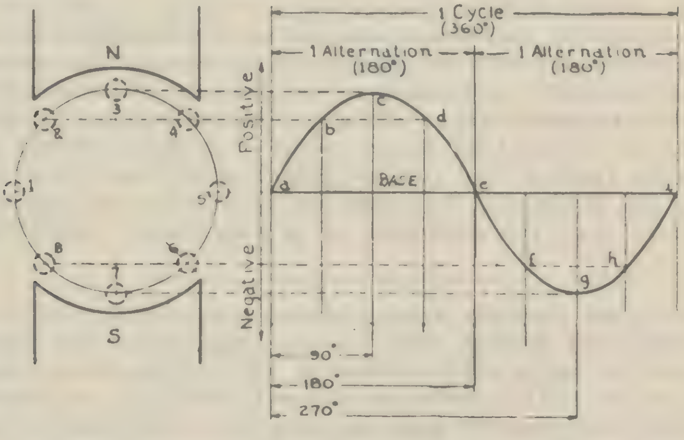
Many times the application of the basic fundamentals of Ohm's Law will enable a serviceman to know why a circuit, no matter on what type of apparatus, will fail to function properly. Ohm's Law is easily remembered and with the application of reasoning, many solutions to electrical problems will become apparent.

SECTION V

NATURE OF A. C. CURRENT

Alternating current is that which periodically changes in value and reverses its direction of flow. The reversal of a direction of flow is caused by the generator rotor conductors passing through a magnetic field, alternating in opposite directions between a north and south pole of the generator stator. Alternating voltage is induced in the conductors of the rotor of any ordinary generator. In order to obtain D.C., it is necessary that the voltage from the rotor of the generator be rectified. This is generally accomplished by means of a commutator. The uses of both A.C. and D.C. are similar in their ultimate functions, to produce heat, light and various magnetic effects. The principal difference between the two currents is that A.C. produces a constantly varying flux. The lines of this flux are always in motion around the current-carrying conductor. This property of A.C. is the means of utilizing magnetic induction to operate transformers, to step up or step down voltage as required.

INDUCTANCE AND CAPACITY - In calculation, A.C. differs from D.C. in that with A.C. two additional factors must be considered. These two factors are inductance and capacity. It must be understood that these two factors are in addition to the factors of voltage, amperage and resistance, normally considered in a standard D.C. circuit. Inductance is set up by the A.C. flux in any A.C. conductor. This action is called self-induction or inductance. In addition to inductance, a constantly changing A.C. voltage will set up capacity in an A.C. circuit. This capacity is also set up by the constantly changing A.C. voltage. When applying Ohm's Law to A.C. circuits, consideration must be given to these two additional factors of inductance and capacity as well as to the effects of resistance when considering any problem involving A.C. circuits.



Generation of Alternating Current

A.C. GENERATION - The above illustration shows the development of an alternating current voltage. For simplification, this illustration represents current obtained from a simple 2-pole generator. The diagram indicates the progress of a conductor through one complete revolution (360 degrees) between the poles of the generator. For simplification, the cycle (one complete revolution of the conductor) is shown between the north and south poles of the generator and also plotted along a horizontal base line. The projected alternation is plotted in time values as well as magnitude of the voltage. It is seen therefore that the intensity of the voltage can be determined at any particular instant from this form of representing the voltage from an A.C. generator.

The values above the base line are considered positive and those values below the base line are considered negative.

From the diagram where the conductor (represented by a circular dotted line) is at position 1 and is revolving in a clockwise direction, the conductor (at position 1) is moving practically parallel to the magnetic field between the north and south poles. At this particular instant it is not cutting any appreciable amount of magnetic lines of force and therefore no voltage will be induced through the conductor. This point projected over to the plotted curve, is seen as point *a* located on the base line. The base line represents zero potential or a point at which no voltage is induced in the conductor.

When the conductor, moving in a clockwise direction, has reached point 2 on the diagram, it is cutting a considerable amount of magnetic lines of force between the poles. Projecting this point to the plotted curve, it is shown as point *b* and, as a certain interval of time has elapsed between points *a* and *b*, the elapsed time would be indicated by moving to the right along the base line. When the conductor has reached point 3, it is cutting the maximum amount of magnetic lines of force. Therefore, projecting this point over to plotted curve at *c*, it will represent the maximum voltage induced in the conductor.

When the conductor of the rotor has reached point 4, it is cutting less lines than it did at position 3 and therefore projecting this point to the plotted curve, it will be shown as point *d*. When the conductor has reached point 5, it is again traveling practically parallel to the magnetic lines of force and there will be no induced voltage in the conductor and therefore point *e* will again be at the base line, indicating no voltage in the conductor. From point 1 to point 5, the conductor of the rotor has traveled through one-half revolution (180°) and this portion of the conductor's travel is called one alternation. When the conductor has reached point 6, it has begun its travel through the second alternation and now the induced current through the conductor is flowing in an opposite direction because the conductor is cutting the magnetic lines of force from the opposite direction. Projecting point 6 out to the plotted curve, point *f* is obtained and as this must be represented as voltage flowing in a reverse direction to that shown from points *a* to *e*, this portion of the curve will be below the base line and points *g* and *h* along the curve are obtained when the conductor is at positions 7 and 8 between magnetic poles.

It can be determined that the travel of the conductor, from point 1 through 8 back to number 1, has moved through 360°. During this travel the conductor has completed one cycle and the cycle will consist of two alternations. The conventional house current used in the United States is 60-cycle current. To generate a 60-cycle current, the conductor will have to make one complete revolution of 360° sixty times per second. Plotting a curve between the points obtained from the induced voltage (points *a* to *i*) a representation of the voltages at various instances during the cycle is shown. This representation of an induced voltage along the conductor is known as a sine wave. By the use of this sine wave form, any type of voltage for any length of time or any magnitude of voltage can be shown for proper interpretation. A complete A.C. cycle will always be shown with part (usually one-half) of the sine wave form above the base line and the other part (usually one-half) below the base line.

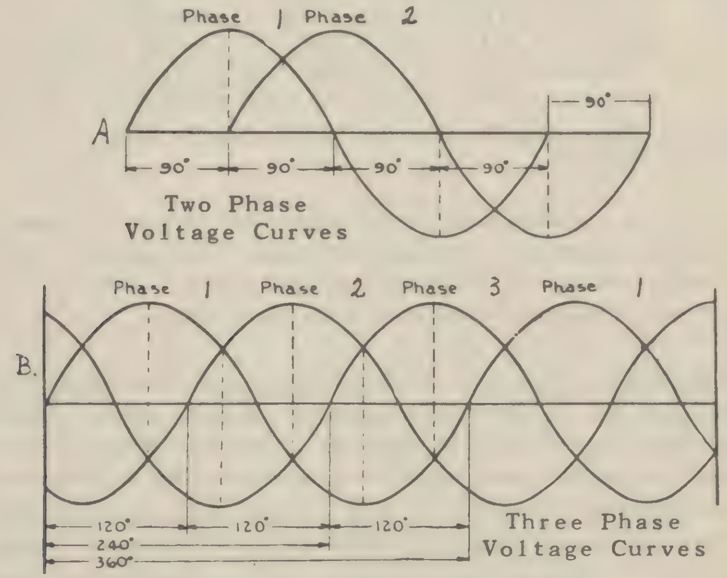
The electrical effects of a sine wave curve, representing a maximum of one volt at one ampere, of A.C. does not equal that which would be delivered by one ampere and one volt of D.C. current. A.C. voltage follows a path from a zero potential up to a maximum and back to zero constantly, while with D.C. voltage, a steady and

constant effect is present on the current-carrying conductor. By actual comparison it is known that the heat produced with A.C. is approximately 70% of that produced with D.C. of equivalent voltage and amperage. The value used to indicate the heat produced by an A.C. as compared to D.C. is .707. This value (.707) is called the effective value of an A.C. circuit. This effective value is considered in A.C. circuit calculations. All A.C. meters of the conventional type are calibrated to read effective values. Therefore, an A.C. circuit employing a certain effective value of 10 volts at 10 amperes will produce exactly the same amount of heat as a D.C. circuit of 10 volts and 10 amperes. When values are given in A.C. voltages and figures indicate peak values (sometimes called maximum values), it will be necessary to multiply by the figure .707 to obtain the effective values. Conversely, if the value is given in effective voltage, the maximum value can be obtained by dividing the effective voltage by .707, or to simplify the problem we can multiply by the reciprocal of the value and will arrive at the formula

Maximum value = Effective value x 1.414

AVERAGE VALUE - There is a third value of A.C. sine wave called "average value" of alternating current. This average value is .636 of the maximum value, which means that it is slightly below the value for effective voltage of the sine wave. This average value is arrived at in the following manner. As the heating effect of an A.C. is proportional to the square of the current values and the true sine wave form is not actually the regular wave shape of the A.C. through the circuit, but rather there are various irregularities in this sine wave form, the average value would be somewhat lower than the effective voltage. For all practical purposes, the average value can be disregarded inasmuch as these values are generally utilized by engineers for purposes of very accurate circuit calculations and electrical designs.

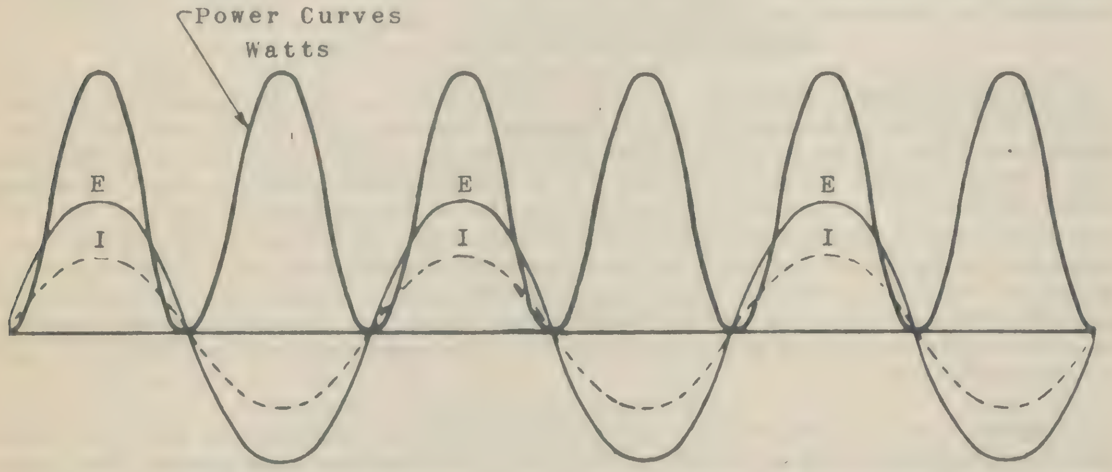
PHASE - A.C. is supplied as either single-phase, 2-phase, or 3-phase. Practically all of the x-ray apparatus utilized by the Army is single-phase. With proper wiring it is possible to operate an x-ray generator from any of the above mentioned power lines. The foregoing illustration represents a single-phase voltage curve.



The above illustration indicates a 2-phase and a 3-phase voltage curve. The 90° differential shown between phase 1 and 2 of diagram A is apparent when considering

the manner in which this induced voltage is generated in the conductor. Illustration B graphically represents a 3-phase voltage curve. Here the phases are 120° apart so that three separate phases manifest themselves in a 360° revolution of the rotor between the two poles.

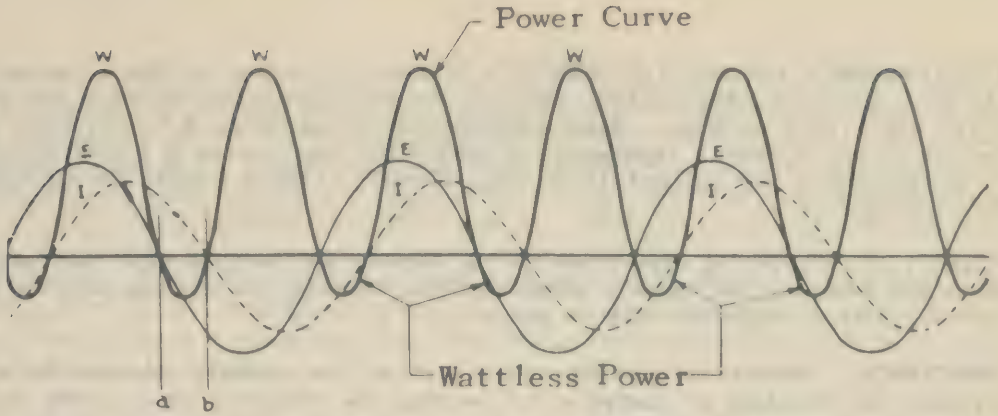
The wiring of a single-phase x-ray apparatus to a 3-phase supply line can be accomplished by connecting the power cable from the x-ray machine across two of the three busses or power terminals of the incoming three-phase power. In addition to 1, 2 and 3-phase circuits, there are other types of polyphase power lines up to 6-phase lines. These are generally used only for special purposes, and will not be encountered in Army installations.



PHASE RELATIONSHIP OF VOLTAGE AND CURRENT - The above illustration shows a single-phase A.C. sine wave with the addition of a power curve in watts wherein the voltage form is shown as a solid line E and the current wave form is shown as a dotted line I. This representation of voltage and current is known as "in phase" because the current and voltage both occupy the same portion of the base line of the sine wave representation. Wattage is the product of voltage times amperage and is shown in this graphic method.

The sine wave form is generally represented by one solid line as in the two previous illustrations. Actually the current wave form and the voltage wave form are not always in exact phase relationship to each other. That is, the current can either lag or lead the voltage wave form to a certain extent.

CURRENT OUT OF PHASE - The last illustration shows the ideal condition whereby voltage and amperage are in exact relationship to each other. This condition does not always exist. Inductance or capacity can cause the current to either lead or lag the voltage and the power obtained from this condition will vary to some extent as compared to instant when the current and voltage are in phase with each other. It is apparent that, if the voltage and amperage are "in phase" they will produce more useful power than if they are out of phase, either leading or lagging.



The above illustration shows the condition whereby the current slightly lags behind the voltage. The voltage is shown as a solid line, the current as a dotted line, and the power curves are shown as the large solid lines marked *w*. From the diagram it can be seen that there is a portion of the time when the current and the voltage are in opposite directions and during this period the power delivered is known as wattless power, or power that has no appreciable effect or ability to produce work. This wattless power is a condition to be avoided if possible, inasmuch as its only effect in the circuit would be to induct additional heating in the conductors without any appreciable efficiency being added to the generator's output.

DETERMINING A.C. CIRCUIT FACTORS - In servicing x-ray equipment, sterilizers and other Medical Department apparatus, it is sometimes essential that various simple calculations utilizing A.C. be used. A thorough knowledge of the basic principles of A.C. will enable the serviceman to calculate various circuit functions in much the same manner as with the conventional D.C. voltages. In determining the flow of current through an A.C. circuit, the similarity to a D.C. circuit is that, when calculating A.C., it must be remembered that the flow of current is traced through the circuit at *one particular instant*. This is essential, inasmuch as the current flowing through the A.C. circuit is constantly reversing itself, increasing and decreasing in intensity.

EFFECTS OF INDUCTIVE REACTANCE, CAPACITY REACTANCE AND IMPEDANCE IN AN A.C. CIRCUIT - As indicated previously, all A.C. circuit calculations must consider two factors in addition to amperes, voltage and resistance. These two factors are inductance and capacity. The opposition or the results introduced into the circuit by inductance or capacity, are known as inductive reactance and capacity reactance respectively. The total results or opposition offered to the flow of current in an A.C. circuit is called impedance. The term impedance of an A.C. circuit can be likened to resistance which is present in a D.C. circuit. Different factors that make up an impedance can be broken down as being composed of resistance and reactance. The subheadings of reactance can be classified into two divisions: one, inductive reactance and the other, capacity reactance. The impedance of an A.C. circuit is converted and measured with the unit Ohm to enable the application of Ohm's law. The symbols used to indicate the factors of A.C. circuits are as follows:

Z = Total impedance in ohms
X = Total reactance in ohms
X_l = Inductive reactance in ohms
X_c = Capacity reactance in ohms
R = Resistance in ohms.

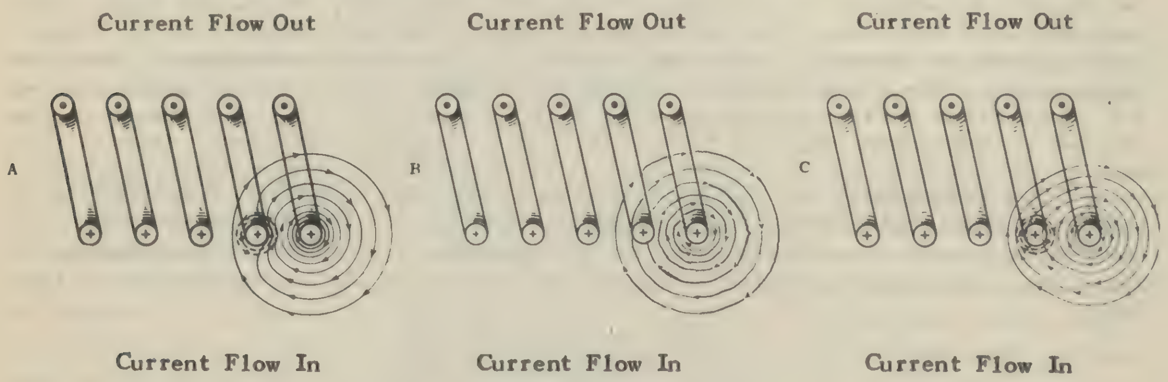
APPLYING OHM'S LAW FOR A.C. CIRCUITS - From the rules of Ohm's Law as applied to D.C. circuits, the current flow can be determined by dividing the voltage by the resistance in ohms. When applying Ohm's Law to an A.C. circuit, substitute the value Z (total impedance in ohms) for the factor R (resistance in ohms). To determine the current in an A.C. circuit, simply divide the voltage by the total impedance.

In addition to offering opposition to the current and voltage, the two factors, inductance and capacity may cause a phase shifting between the voltage and the amperage curves, with a resultant loss of power.

INDUCTANCE - Inductance can be summarized as the quality of an A.C. electric circuit that develops a counter e.m.f. within the circuit. This is the result of variations or changes in the magnetic flux surrounding the conductor which are caused by the changes in current flowing in the circuit. The amount of inductance in a circuit will vary considerably. The amount of inductance in some circuits is so slight that for all practical purposes it can be disregarded. However, the inductive effect in many circuits is great enough that the entire function of the complete circuit is definitely effected; therefore, inductance must be considered.

The development of an inductance in an A.C. circuit is caused by the changing flux as it cuts across the conductors of the circuits. An A.C. circuit that has coils of various types will have greater inductance than a circuit which employs straight wires or devices similar to conventional incandescent lights. The circuit containing the lights or the straight wires does not have any fields of concentrated magnetic flux. The circuit employing coils will have considerable magnetic flux and thereby generate considerable counter e.m.f. of self-induction. The use of an iron core in a device will generally indicate that the circuit employing this device will have a high inductive e.m.f. because of its very strong magnetic fields.

The following three illustrations indicate three phases of counter-voltage of induction being set up in conductors of a coil. It can be seen that when the voltage is being built up through the conductor, the lines of force are in a clockwise motion and are to a certain extent out of a true concentric position, but in the second illustration where the current is at a maximum value, the flux has cut across the flux of the second turn, and in the third illustration where the current is decreasing from the maximum to a zero point the flux is tending to contract. These simple illustrations show the manner in which the counter-voltage of self-induction is set up in a coil of copper conductors.



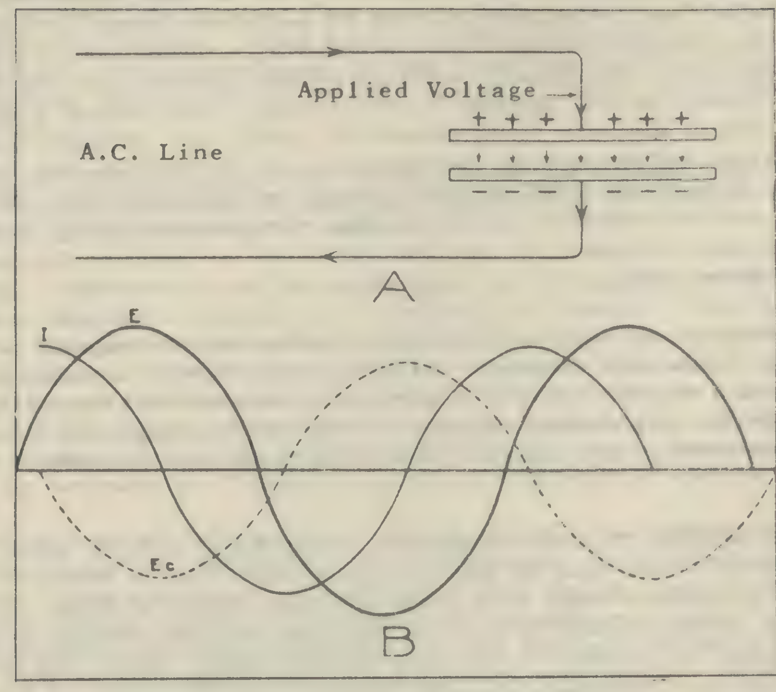
Direct current has a constant value, it does not have a continual varying or moving flux to set up the counter-voltage of self-induction. If certain devices built to operate on A.C. voltage, were accidentally connected to a D.C. line the device will burn out. Inductance is always present with an A.C. circuit. Counter-voltage, (self-induction) is the result when current flows through a conductor, thus setting up a strong magnetic field around it. With A.C. voltage, due to the constantly increasing and decreasing characteristic of the voltage and the reversal of its direction, this counter-voltage will always tend to oppose the applied voltage. Therefore, it can be summarized by saying that electromagnetically induced currents always flow in such a direction that the field set up tends to oppose or stop the force that produces them.

The addition of an iron core through a coil will allow a much stronger field to be built up. With this stronger field it is possible to increase the inductance of a coil. Such a device is called a choke coil because of its choking effect upon the flow of alternating current through it. In A.C. circuits the inductive reactance or counter-voltage may control the current even more than ohmic resistance of the coil.

INDUCTION APPLIED TO X-RAY APPARATUS - When doing service work, bear in mind that a resistance of one type or another may be used. It is well to remember that induction and counter-voltage will cause various choking effects in the circuit. Using a device of the inductive type in the high tension primary circuit has the effect of causing the current to lag to a certain extent behind the voltage curve. This will result in a poor wave form and decrease the efficiency of the x-ray output from the tube. If any resistance is installed in the primary of the high tension circuit, it should be of the non-inductive type. The non-inductive type resistance will not affect the phase relationship between the voltage and current curve through the primary of the high tension transformer. Should an inductive type resistance be placed in the primary circuit, the extent of phase shift will be a function of the size and amount of inductance inserted in that circuit.

CAPACITY - Capacity is an important factor in considering calculations for A.C. circuits. This term indicates the tendency to store an electrostatic charge. This effect is also indicated as condenser effect in the circuit. A conventional condenser consists of two or more conductive surfaces separated by an insulator composed of various materials or a dielectric. The amount of charge in a condenser depends entirely upon the capacity of the condenser and the voltage applied. On low voltage circuits of comparatively short length, the condenser or capacity effect can be disregarded due to the small amount present. On the other hand, on high voltage lines of considerable length, the capacity in the conductors must be given consideration due to its effect upon the applied voltage in the circuit. Capacity is measured by the unit farad. A device has a 1-farad capacity when a charge of one coulomb will raise the condenser potential one volt. The common denomination for considering capacity effects is one micro-farad (1/1,000,000 of a farad) and the symbol for farads or capacity is the capital letter C.

CONDENSER CHARGING CURRENT - When voltage is first applied to the terminals of a condenser, as shown in the following diagram, a current will at once start to flow into the condenser to store up its electrostatic charge. If the direction of the applied voltage and current for the instant are as shown by the arrows in this diagram the top plate of the condenser will become positively charged and the lower plate negatively charged, as shown.



This diagram shows the current leading the voltage by nearly 90°, due to capacity or condenser effect in the circuit.

When the voltage is first applied to a condenser and before its plates have had time to build up a voltage charge, the current flow into the condenser will be very rapid, and at maximum value, even though the applied voltage is still very low. This is illustrated by the curves in the same diagram, Section B. The curve E represents the applied voltage; the curve I, the current flow to the condenser; and the dotted curve Ec, the counter-voltage of the condenser.

Note at the first curve on the left, the current reaches maximum value just a little later than the applied voltage starts from zero value. Then, as the applied voltage keeps on increasing, the counter-voltage, Ec, of the condenser is building up and reduces the flow of current, until it reaches zero value just after the applied voltage reaches maximum.

In this circuit, therefore, the current leads the voltage by nearly 90 degrees. If it were possible to have a circuit with all capacity and no resistance, the current would lead the voltage by 90°.

When the applied voltage passes its maximum value and starts to decrease, the condenser starts to discharge, causing the current to flow in the reverse direction just after the applied voltage reaches maximum.

As the condenser discharges, its counter-voltage decreases as shown by the dotted curve Ec, until it reaches zero value just a few degrees later than the applied voltage.

When the alternating voltage reverses, the current flows into the condenser in the opposite direction and charges its plates with opposite polarity.

In this manner a condenser receives its maximum current as the applied voltage reverses and starts a new alternation, then the condenser discharges its current ahead of the next voltage reversal, causing the current in such a circuit to lead the voltage.

Current does not actually flow through a condenser as long as its insulation is not punctured, but the rapid flow of alternating current in and out of a condenser as it charges and discharges, provides a flow of current that can be measured by an ammeter or used to operate devices, just as though it actually flowed through the circuit.

The amount of the charging current is proportional to the size or capacity of the condenser, and is also proportional to the amount and frequency of the applied voltage.

Condensers in a D.C. circuit do not allow any current flow except during the first instant that the voltage is applied, and while the condenser is taking its charge. If a condenser which has been charged in this manner is short-circuited, it will discharge its energy in one violent rush of current.

The calculation of an A.C. circuit with the presence of impedance, inductance, capacity, etc. requires considerably more knowledge of electricity than is provided graduates of this school. The Medical Department Technician will not have many occasions to use this type of calculation. The following points in A.C. circuits should be kept in mind:

Inductance capacity will be present in A.C. circuits consisting of coils transformers, motors, generators, choke coils, and current limiting reactors. A.C. circuits, where capacity effects will be experienced, are those circuits employing continuous or long power lines. The effects of various types of inductance can be summarized with the understanding that inductance will cause a phase shift in which the current will lag behind the voltage. Capacity and condenser effect will oppose voltage and cause the phase to shift so that the voltage will lag tne current. Excessive inductance in a circuit is detrimental to the power carrying capacity, since it will cause excessive amount of wattless power and this additional power will only create unwanted heat in the conductors. Excessive capacity in a circuit also is detrimental to the power carrying capacity due to the phase shift.

The low power factor which is the result of either of the above conditions (excessive inductance or excessive capacity) can be neutralized by the use of one or the other. Excessive capacity can be neutralized by the introduction of inductance into the circuit. Excessive inductance causing low power factor can be corrected by the addition of capacity into the circuit. It is well to remember that a power factor correction does not present a problem to the serviceman under ordinary circumstances and if this condition exists, particularly in the production of radiographs, it can generally be determined through the inability to obtain proper radiographic densities with standard technique factors.

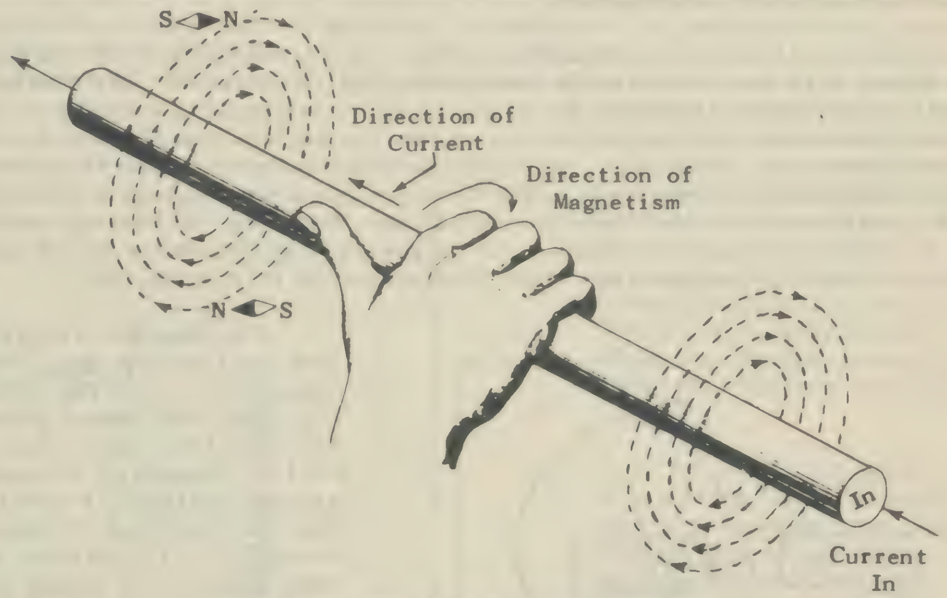
Questions have arisen regarding the difference of interpretation of KVA and KW. KVA rating indicates the apparent power of an A.C. circuit and the ability of the circuit to perform work. It is not always equal to the rating in KW. The true power of a circuit will be registered on an A.C. wattmeter and therefore the power factor of the circuit or device can be determined by dividing the true power by the apparent power factor.

SECTION VI

ELECTROMAGNETIC INDUCTION

The basic knowledge of magnetic induction and how its various functions are performed is of vital interest inasmuch as generators, motors, transformers and many other electrical devices operate on the principle and by means of magnetic induction.

By means of simple compass experiments it can be demonstrated that a magnetic field always surrounds an electric current-carrying conductor. It is also easily determined that the extent of this magnetic field depends upon the amount of current flowing through the conductor. The direction of the lines of force that make up this magnetic field depend entirely upon the direction of flow of the current through the conductor.



Application of the Right-Hand Rule

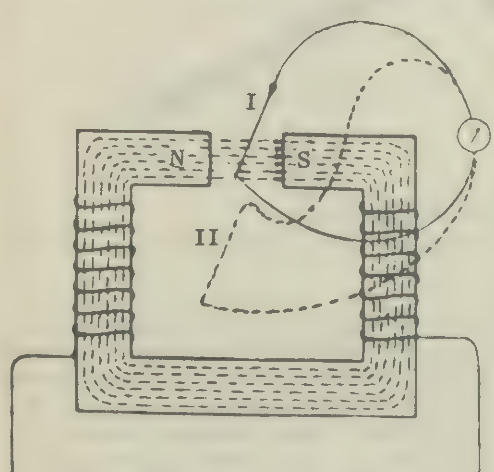
The right-hand rule is a very simple method of determining the direction of the lines of force surrounding a conductor. It can be seen in the illustration above that the current is flowing in from the lower end of the illustration and by application of the right-hand rule, the thumb indicates the direction of current and the fingers, wrapped around the conductor, the direction of the lines of force for the magnetic field. If the current were to be flowing in the opposite direction and were coming out of the lower end of the illustration, the right-hand rule would still apply inasmuch as the thumb would point in the opposite direction and the lines of force would then be operating in a counter-clockwise direction. It must be understood that the illustration only shows two sets of concentric circles surrounding the conductor. Actually this magnetic field will extend the entire length of the conductor.

A coil of wire would intensify the magnetic field around these conductors inasmuch as the magnetic lines would become intensified due to the proximity of the magnetic fields surrounding each wire. By use of a simple compass test, the magnetic field on the inside of this coil would be found to have a definite North and South pole similar to bar magnets. If an iron bar is inserted in the center of the

coil, made of the copper conductors, a powerful magnet would be created in the iron core. This is proof of the great ability of iron to gather and convey lines of force. It has been estimated that iron will convey as high as 1,500 times the lines of force that can be conveyed in air; therefore iron is said to have a permeability approximately 1,500 times that of air. For this reason, iron cores are used in various devices such as breakers, transformers, etc., as used on X-ray and other similar equipment.

We have definitely determined that the flow of electricity is along a conductor. This conductor can be either wire, pipe, or various conducting materials. As copper wire is the conductor most frequently encountered, we can determine that a magnetic field surrounds a current-carrying conductor much in the same way that lines of force surround a conventional magnet.

The previous illustration shows the directions of the lines of force that surround a copper wire when the wire is conducting electric current. For service work, the functions and rules regarding the magnetic field surrounding a conductor may not be of vital importance, but the principle of how the various transformers function is of extreme importance. Therefore, an understanding of the magnetic field surrounding copper conductors is important. The lines of force surrounding a conductor are always at right angles to the conductor itself and therefore, by knowing the direction of a current through a conductor, it is possible to determine the direction of the lines of force in the magnetic field that surrounds this conductor.

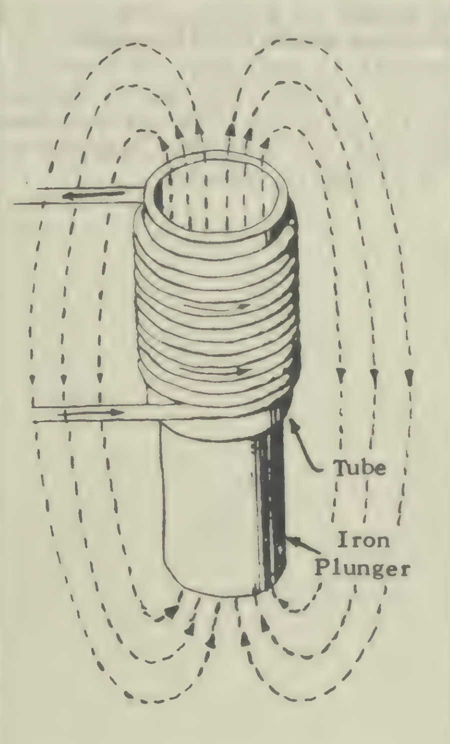


When the wire is moved across the magnetic field, an induced electromotive force is developed in the wire.

The diagram illustrates an iron core with a gap. Insulated copper wire in the form of a coil has been wound around two legs of this iron core. This coil is energized by means of a storage battery. A small switch has been inserted in the battery circuit. If a single turn of copper wire, not in any way connected with the iron core or coil, connected to a voltmeter (of a low range), were moved through the gap in the iron core the voltmeter would give a slight indication. This will prove that, whenever a portion of any circuit is moving with respect to magnetic lines of force, an induced electromotive force (E.M.F.) is developed and if the circuit is closed an induced current results. To explain the action that has taken place to cause this induced E.M.F., recall in the study of magnets, a magnetic field of force was shown to exist and surround the area immediately surrounding the magnet. The intensity of the magnetic field of force can be increased many times by wrapping turns of copper wire around a bar

of iron and applying voltage to this coil. At the same time, the strength and power of the lines of force and the magnetic field surrounding the magnet are also increased.

This can be shown in a simple manner as follows; when the single turn of wire is in position II there are no lines of force linked with the voltmeter circuit, but when it is in position I the lines are interlocked with the circuit. If the coil were left in position I and the switch to the storage battery were opened, there would be a momentary induced voltage in the single turn of wire and it would register on the meter. If the switch were open, the meter would again register momentarily. It then appears that, to have an induced E.M.F. it is not necessary to physically move the single turn of wire (which represents the secondary circuit of a transformer), but the same effect can be accomplished by alternately reducing or increasing, or alternately turning the voltage that is going into the primary of the transformer, on and off. When the circuit is closed the magnetic lines are said to be linked with the turns of the circuit, the number of linkages being equal to the product of the total magnetic flux times the number of turns of the circuit with which they are linked. The magnitude of the induced E.M.F. is found to depend upon the *rate* at which the magnetic lines are cut or on the rate at which the number of linkages are changing. This is the basic principle utilized in the designing of transformers, dynamos and induction coils.



The Solenoid with a Plunger

It should be apparent that alternating current must be used for electromagnetic induction since it is known that alternating current of 60 cycles means that the direction of flow in a conductor being supplied by a generator will change its direction of flow once every half cycle (1/120 of a second). Therefore, the rate of change in the magnetic lines of force around the conductors depends not only upon the incoming voltage but also upon cycles of the voltage. The efficiency will depend on the size and permeability of the iron core, and the size of the conductors that make up the transformer.

The principle of the solenoid coil is utilized in many ways and for various uses. It is employed in the operation of many various types of relays and breakers used throughout X-ray apparatus.

The above illustration shows a coil wound on an insulated tube, with a plunger free to slide in and out of the center of the coil. By energizing the coil as shown by the direction of the arrows entering and leaving the coil, a magnetic field surrounds the coil. If an attempt is made to remove the iron plunger from this coil, the magnetic field would exert a considerable force upon the iron plunger and considerable effort would be required to remove the plunger from inside of the coil. If the plunger were allowed to enter the center of the coil, it would be found that the plunger would align itself up exactly in the center of the coil. With the above arrangement either end of the iron plunger would act as a powerful magnet.

This principle is utilized by many X-ray manufacturers as a means of controlling the heat of the filament of the X-ray tube. The means of regulating this heat must be in the primary of the filament circuit inasmuch as the secondary of the filament is in the high tension circuit. Therefore, to control the amount of filament heat in the X-ray tube, some means of controlling the incoming voltage to the primary is required. This arrangement affords the operator perfect control over the amount of milliamperage that will go through the X-ray tube. The device used is called either a choke or a self-inductance coil. It is similar to a solenoid coil, except the control of the voltage going to the primary of the transformer is obtained by the movement of an iron core through the center of a coil. The field around any one turn of the coil will cut across the other conductors of the same coil as it builds up and collapses. In doing this, a current is generated in each of these turns even though these turns at the same time are carrying current producing this magnetic field. There is always self-induction in any coil. The current formed by this self-induction is generated in such a way that its direction opposes that of the current which sets it up; in other words, it is counter E.M.F.

SECTION VII

ALTERNATING CURRENT METERS

Ordinary A.C. meters consist of: The moving element, which is delicately balanced, mounted on bearings and has the pointer or needle attached to it; a controlling force or spring to limit the movement of the pointer and movable element; a stationary coil or element to set up a magnetic field; a damping vane or element to prevent vibration or excessive "throws" of the pointer; and the meter scale and case.

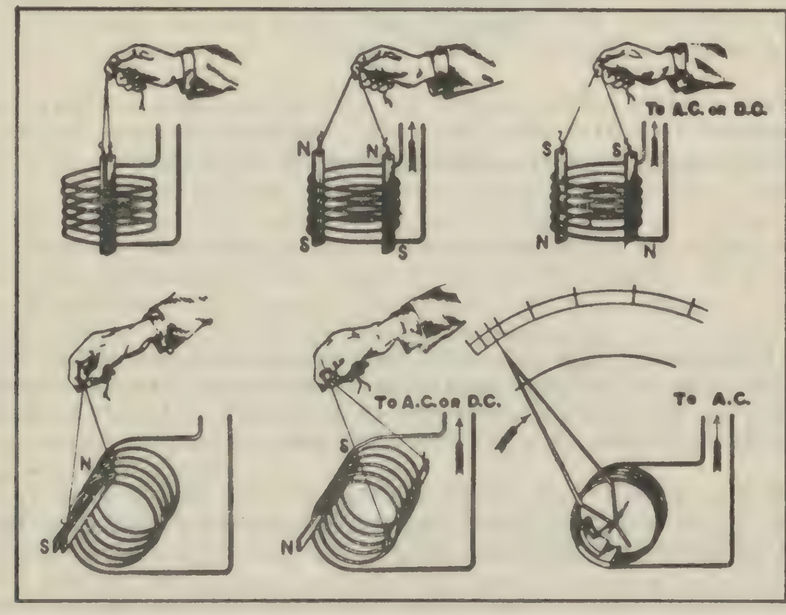
One of the principal differences between A.C. meters and D.C. meters is that, while certain types of D.C. meters use permanent magnets for providing the field in which the moving element rotates, A.C. meters use coils instead.

Some types of A.C. meters, also, operate on the induction principle, which is not used in D.C. meters.

TYPES OF A.C. METERS - There are several different types of A.C. meters each of which uses different principles to obtain the torque for moving the pointer. Some of the most common of these types are: The moving-iron repulsion type; inclined coil and moving vane type; dynamometer type; induction type; and hot-wire type.

Some types of A.C. meters can be used on D.C. circuits with fair results, however, under this condition they are not as accurate as D.C. meters.

MOVING IRON TYPE INSTRUMENTS - The moving-iron principle used in some makes of A.C. voltmeters and ammeters is illustrated by the several illustrations shown below. This is one of the simplest principles used in any type of alternating current meters, and is based upon the repulsion of two soft pieces of iron when they are magnetized with like polarity.



The above views illustrate the principle of the moving-iron type meter. Note how the iron bars repel each other when they are magnetized with like poles, by the flux of current through the cells.

If two pieces of soft iron are suspended by pieces of string within a coil, as shown in the upper left-hand view of the illustration, and current is passed through this coil, the flux set up within the turns will magnetize the two parallel pieces of iron with like poles at each end. The repulsion of like poles will cause the two iron strips to push apart, as shown in the top center view. This effect will be produced with either D.C. or A.C. flowing in the coil. It makes no difference if the poles of the iron strips do reverse, as long as like poles are always created together at the top and bottom ends of each strip.

The view at the upper right shows the poles reversed, and the strips still repel as before. They must, of course, be made of soft iron so their polarity can reverse rapidly with the reversal of the current.

Now, if the two iron strips are again suspended in a horizontal coil, as shown in the lower left view, and one of the strips is rigidly attached to the side of the coil and the other suspended by a string so that it is free to move, the strips will again repel each other or push apart when current is passed through the coil, as shown in the lower center view.

The view at the lower right shows how this principle can be applied to move the pointer of the meter. One small piece of soft iron is attached to the coil in a fixed position as shown. The other piece is attached to the movable element or pointer, which is mounted on a shaft and pivots, so it is free to move.

When alternating current is passed through the coil, the two iron vanes are magnetized with like poles, and the repulsion set up between them causes the movable one to rotate in a clockwise direction and move the pointer across the scale.

A.C. VOLTMETERS AND AMMETERS - This principle and method of construction can be used for both voltmeters and ammeters, by simply making the coil of the proper resistance and number of turns in each case.

A.C. ammeter coils usually consist of a very few turns of large wire, as they are always connected in series with the load. Ammeters designed for use with shunts or current transformers, however, usually have coils of smaller wire and a greater number of turns.

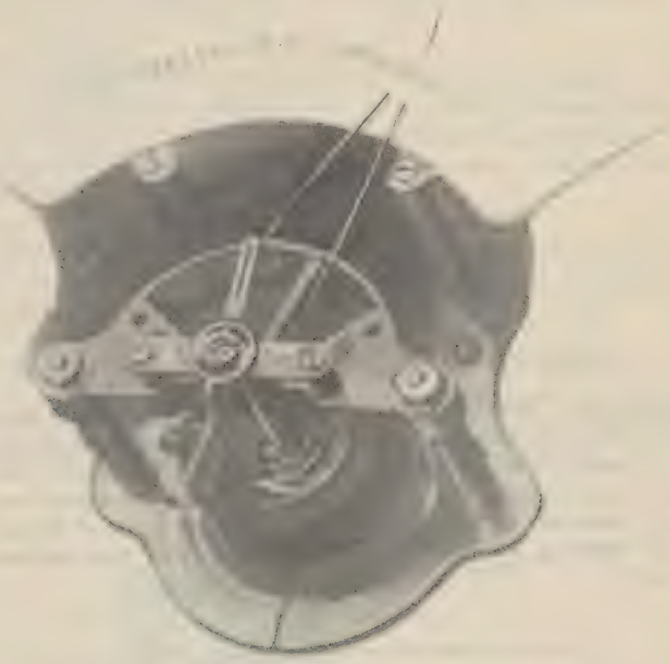
Voltmeter coils are wound with a great number of turns of very fine wire, in order to obtain high enough resistance so they can be connected directly across the line.

Separate resistance coils are sometimes connected in series with the coils of voltmeters to provide sufficient resistance to limit the current through them to a very small amount. The current required to operate a voltmeter usually does not exceed a very few milliamperes (1/1000 of an ampere).

The following illustration shows a meter of the moving vane type. The iron vanes are made in several different shapes, but always operate on the same principle of the repulsion between like poles.

Some meters of this type depend upon the weight of the moving iron vane and a small adjustable counter-weight to react against the magnetic force as the pointer is moved across the scale. Other meters use a small coil spring to oppose the pointer movement.

This type of meter can be used on D.C. circuits also, but may not be as accurate; because of the tendency of the iron vanes to hold a little residual magnetism from the constant direct current flux which is applied to them.



This photo shows the construction and important parts of an iron-vane meter. Note the position and shape of the iron vanes within the coil and also note the damping vane and chamber above the coil.

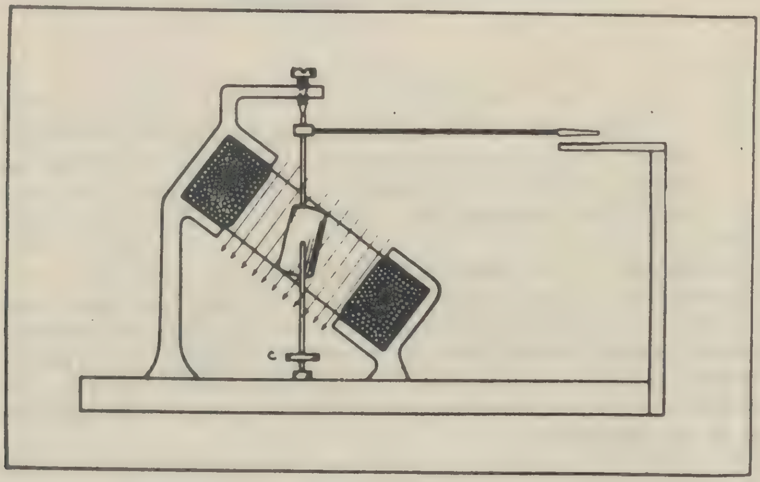
DAMPING OF METERS - The damping chamber can be seen directly behind the lower part of the pointer in the above photo. The damping vane, made of very light weight material and attached to the pointer, moves in this air chamber as the pointer moves. This vane doesn't touch the sides of the chamber but fits closely enough so that it compresses the air on one side or the other as it moves in either direction. This prevents oscillation of the pointer with varying loads and permits more accurate readings to be obtained.

For damping the pointer movement some instruments use a small aluminum disk which is attached to the pointer and moves between the poles of the permanent magnet, the retarding effect being produced by the eddy currents induced in the disk.

The following illustration shows the movable assembly of the moving-iron type of instrument, on which can be seen the damping vane, mounted directly beneath the pointer, and also the movable iron vane at the lower end of the shaft, and the small coil spring which controls the pointer movement across the scale.

Moving element of an iron-vane type meter. This view shows the shaft, iron vane, damping vane, pointer, and spring.

INCLINED COIL INSTRUMENT - The inclined coil and moving vane type of construction is quite extensively used in some makes of A.C. voltmeters and ammeters. This type of meter uses a coil inclined at an angle of about 45 degrees with the back of the instrument, as shown below. The coil supplies the flux to operate a small moving vane of soft iron, which is also mounted at an angle on the shaft of the meter so that it is free to move and operate the pointer which is attached to the same shaft.



The above diagram shows the construction and principle of the Thompson inclined-coil meter.

When the meter is idle and has no current flowing through the coil, the small coil spring at "C" holds the pointer at zero on the scale. When the shaft is in this position, the movable iron vane is held at an angle to the axis of the coil or to the normal path of the flux set up by the coil when it is energized.

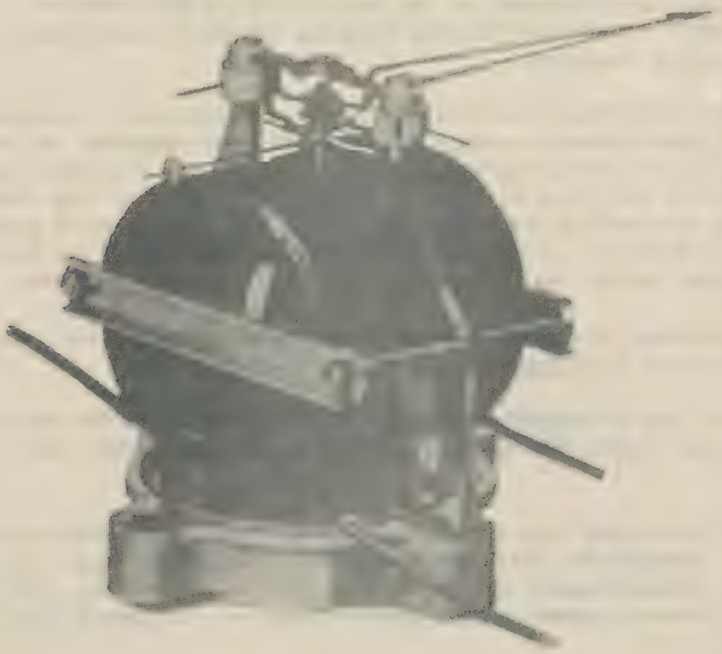
When the coil is energized and sets up flux through its center, as shown by the arrows, the iron vane tends to move into a position where its length will be parallel to this flux. This causes the pointer to move across the scale until the magnetic force exerted is balanced by the counter-force of the spring.

This type of construction is used both for voltmeters and ammeters, by winding the coils with the proper number of turns.

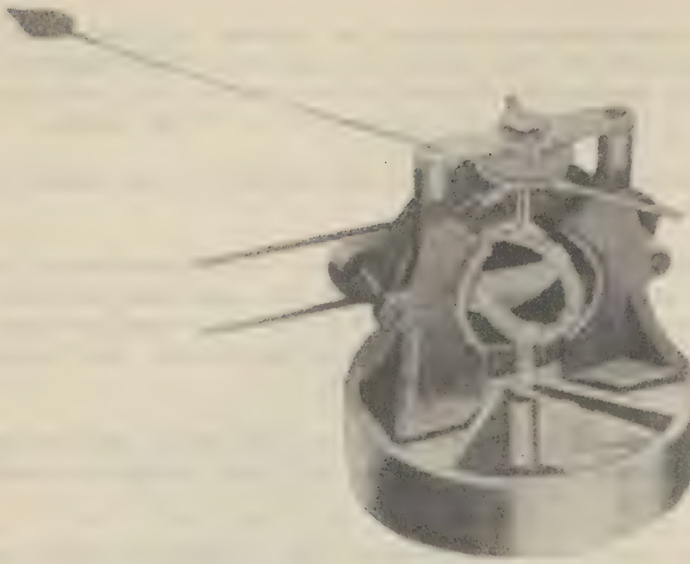
DYNAMOMETER TYPE INSTRUMENTS - Dynamometer type instruments are used for voltmeters, ammeters, and wattmeters. Meters of this type have two coils, one being stationary and the other movable and attached to the shaft and pointer. The torque which moves the pointer is produced by the reaction between the fields of the two coils when current is passed through them both.

There is no iron used in the two elements of this meter; the moving coil being light in weight and delicate in construction, but rigid enough to exert the proper torque on the shaft.

In some meters of this type, the movable coil is mounted within two stationary coils, while in other types it is mounted near to the side of one large coil, as shown in the following illustrations. In either case, the movement of the smaller coil is caused by the reaction between its flux and the flux of the stationary coil or coils.



This view shows the coils of an electro-dynamometer type meter.



Another dynamometer type meter with slightly different arrangement of the coils. Note the damping vane attached to the bottom end of the shaft so that it rotates in the damping chamber under the meter element.

When both the stationary and movable coils are excited or energized, the lines of force through their centers tend to line up or join together in one common path. When the pointer is at zero, the movable coil rests in a position so that its axis and the direction of its flux will be at an angle to that of the stationary coils. When the current is applied the reaction of the two fields will cause the movable coil to force the pointer across the scale against the opposing force of the delicate coil springs, which can be seen in both illustrations shown.

These coil springs are usually made of phosphor bronze alloy, and in some cases they carry the current to the movable coil.

Voltmeters of the electro-dynamometer type usually have the two coils connected in series with each other and also in series with a resistor, and then connected across the line.

Ammeters of this same type may have the two coils connected in series and then across a current transformer which carries the main load current. In some cases the stationary coil of an ammeter may carry the full load current, while the movable coil is connected to a current transformer so that it carries only a small fraction of the current.

The movable coil is not designed to carry much current in any case, because it must be light in weight and delicate in construction to obtain the proper accuracy in the operation of the meter.

A.C. WATTMETERS - Wattmeters using the electro-dynamometer principle have elements very similar to those shown. The stationary coils are used for the current

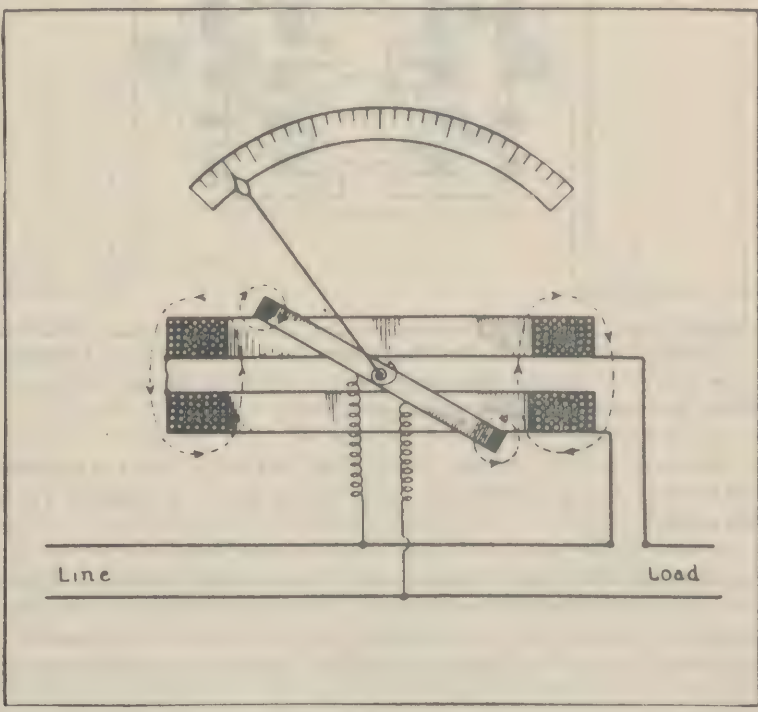
element and may be connected in series with a load or across a current transformer. The movable coil is the potential coil and is connected in series with a resistance, and then across the line.

Resistances used in connection with the coils of A.C. meters are generally of the non-inductive type, so they will not affect the reading of the meter by introducing inductive reactance in the circuit.

While shunts are used in some cases with certain types of A.C. meters, instrument transformers are also commonly used to reduce the amount of current and voltage applied to the coils of the meters. This eliminates the necessity of winding potential coils with a great number of turns to obtain high resistance to permit them to be connected across high-voltage lines. It also reduces insulation difficulties, and hazards in testing high voltage circuits.

As the current coils in the wattmeter will always carry a current proportional to the amount of load, and the potential coil will carry a current proportional to the voltage applied to its terminals, the torque set up by the magnetic fields of these two coils will be proportional to the power in watts in the circuit. The scale can therefore be graduated and marked to read directly the watts or kilowatts of the circuit to which the meter is connected.

Since the torque acting on the movable element is proportional to the instantaneous current and voltage, the meter will register the true power of the circuit, regardless of the power factor.



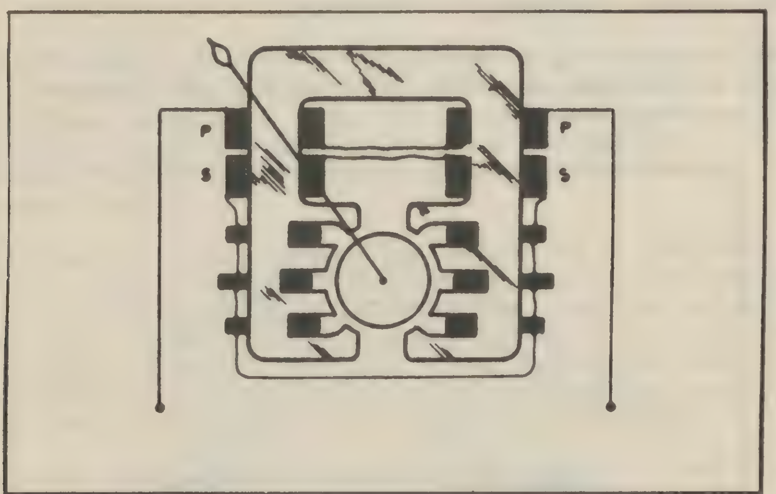
This diagram illustrates the construction and principles of the dynamometer type instrument. Note the action between the flux of the moving and stationary coils.

The preceding sketch further illustrates the principle of the dynamometer-type wattmeter. Note that the stationary current coils tend to repel the flux of the movable coil and will cause it to move the pointer across the scale to the right.

Electro-dynamometer type meters are somewhat more delicate and less simple in construction than the moving iron types, but the former are more accurate and therefore generally preferred where exact measurements are desired.

The scale over which the pointer of this instrument moves is not graduated with spaces of even width, because of the fact that the opposing force is a spiral or helical spring and, therefore, becomes greater as the pointer moves farther from zero.

INDUCTION TYPE INSTRUMENTS - Induction type A.C. meters operate on a principle similar to that of an induction motor, using the magnetic flux of stationary coils to induce currents in a rotating element in the form of a metal cylinder or drum, or in some cases a metal disk.



This diagram shows the core and coils of an induction type meter. Study the principles of this meter thoroughly with the accompanying explanations.

The above shows a sketch of an induction meter of this type which can be used either as a voltmeter or an ammeter, according to the manner in which coils are wound and connected.

A set of primary coils and also a set of secondary coils are wound on the upper part of the iron core. The primary coil, being connected to the line, sets up alternating magnetic flux which magnetizes the core and also induces in the secondary coils a current which is out of phase with that in the primary.

These secondary coils are connected in series with a third set of coils wound in slots at the lower end of the core near the movable drum. The different phase relations between the currents of these coils tend to set up a flux which is out of phase with that established in the core by the primary coil, thereby producing a revolving field which induces eddy currents in the drum. The reaction between

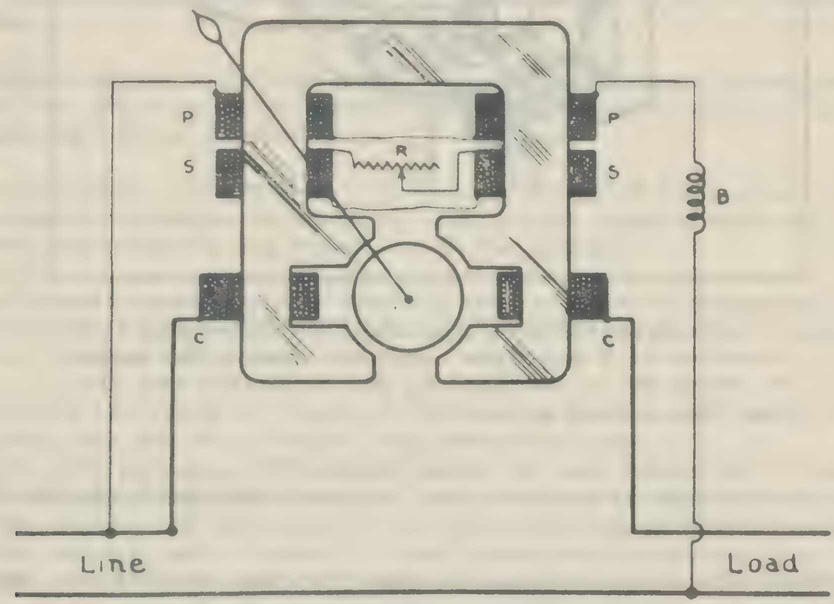
the flux of these eddy currents and the flux set up by the coils then causes the drum to rotate by the same principle as used in A.C. induction motors.

The pointer is attached to this drum, so that, when the drum is rotated, the pointer is moved across the scale against the action of the coil springs.

When an instrument of this type is used for an ammeter, the primary coil is wound with a few turns of heavy wire and is connected in series with the line, or it can be wound with small wire and connected in parallel with a shunt or to the terminals of a current transformer.

When used as a voltmeter, the primary coil is wound with more turns of fine wire and is connected in series with a resistance and then across the line.

INDUCTION TYPE WATTMETERS - This same induction principle can be applied to wattmeters, as shown below.



Core and coils of an induction type wattmeter. Note how the current and potential coils are connected to the line.

In this case, the potential element consists of the primary Coils "P" which are connected in series with a reactance coil "B", and then across the line. The secondary coils "S" have current induced in them by the flux of the primary, and are connected in a closed circuit with a variable resistance "R".

In this manner, the amount of induced current which flows in the secondary coils may be varied by adjusting the resistance, so that the reaction will produce the proper phase relation between the flux set up in the core and the flux of the current coils "C", which are wound in slots near the movable drum.

This current element is connected in series with the line, or to the proper shunt or instrument transformer.

When both sets of coils are excited, a revolving field is set up, which induces eddy currents in the movable drum.

In this case the strength of the combined flux set up by the potential and current coils will be proportional to the product of the voltage and current of the line. So, with proper graduation of the scale, this meter can be made to record directly in watts the power of the circuit to which the meter is attached.

SHADED POLE INDUCTION METERS - Another type of induction meter which uses the induction disk, or shaded pole principle, is illustrated below.

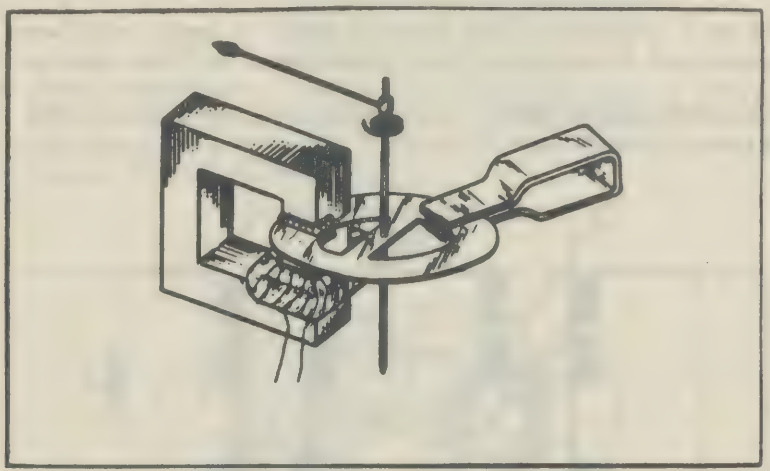


Diagram illustrating the principles and construction of a disk type induction meter. The torque on the disk is produced by the action of the flux from the shaded pole.

This type of instrument has the torque produced on a moving disk, by inducing eddy currents in the disk by means of the large exciting-coil, and small shading coils, on the soft iron core.

When alternating current is passed through the large coil it sets up an alternating flux in the iron core and induces eddy currents in the edge of the disk which is between the poles of the core. The flux also induces secondary currents in the small shading coils, which are built into slots in one side of the pole faces and are short-circuited upon themselves to make closed circuits.

The induced currents in these shading coils are out of phase with the current in the large coil, and therefore they set up flux which is out of phase with the main core flux. This causes a shifting or sliding flux across the pole faces, which reacts with the flux of the eddy currents in the disk and causes the disk to tend to rotate.

The disk can rotate only part of a revolution, as its movement is opposed by a spring on the shaft. The rotating movement of the disk moves the pointer across a scale as in any other meter.

The movement of the disk and pointer is damped by the drag magnet on the right, which induces eddy currents in the disk when it moves and thereby tends to slow its

movement and prevent jumping or oscillation of the pointer.

The sides of the moving disk or ring are often cut in a slightly varying or tapering width, to obtain greater torque as the pointer moves farther against the force of the spring. This allows uniform graduation of the scale.

When instruments of this type are used for ammeters, the main coil is connected in parallel with a special alloy shunt, the resistance of which changes with temperature and load changes, to compensate for heat and increased resistance in the coil or disk.

When used as a voltmeter, the coil of the instrument is connected in series with a reactance coil to compensate for changes in frequency, and also in parallel with a shunt to compensate for temperature and resistance changes.

This same principle of induction is applied to A.C. induction watthour meters, frequency meters, and various types of A.C. relays; so it is well worth thorough study to obtain a good understanding of the manner in which it produces the torque in the disk.

FREQUENCY METERS - A frequency meter is an instrument which, when connected across the line the same as voltmeters are connected, will indicate the frequency of the alternating current in that line.

There are many cases where it is necessary to know or maintain the exact frequency of certain circuits or machines, and in such cases a frequency meter is used to determine conveniently the frequency of the circuit.

Power plants supplying A.C. usually regulate the frequency very carefully so that it will remain constant (60 cycles per second) at whatever frequency the generators are intended to produce.

There are two types of frequency meters in common use, one known as the vibrating-reed type and the other of the induction type.

VIBRATING-REED TYPE INSTRUMENT - A vibrating-reed instrument is a very simple device, consisting principally of an electro-magnet which is excited by the alternating current, and a number of steel reeds which are like thin, flat springs. These reeds are caused to vibrate by the changing strength and reversing flux of the magnet.

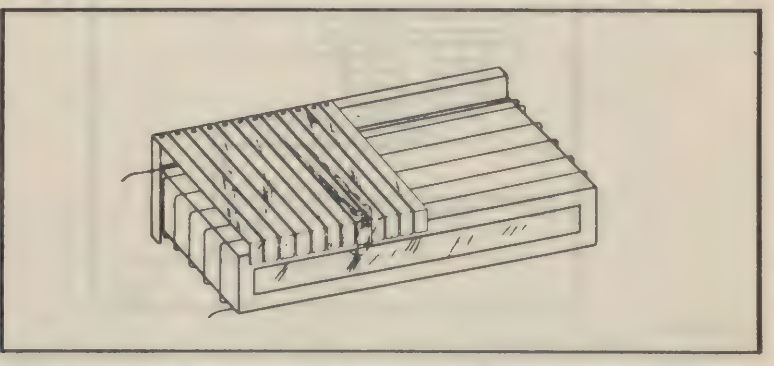


Diagram of a vibrating-reed type frequency meter. Only part of the reeds are shown in this view. Note the appearance of one reed which is vibrating more than the others.

The preceding illustration shows the principle of this type of frequency meter. The large electro-magnet is wound with a coil of fine wire which is connected in series with the resistor and across the line. When alternating current is passed through this coil, it magnetizes the core first with one polarity and then another.

The polarity is constantly reversing and varying in strength, in synchronism with the frequency of the current. This causes the ends of all the steel reeds to be slightly attracted each time the end of the magnet becomes strongly charged.

These reeds are about 1/8 of an inch wide and approximately 3 inches long, but they each have slightly different natural periods of vibration. In other words, they are somewhat like tuning forks which will vibrate more easily at certain frequencies, depending upon the weight and springiness of the elements.

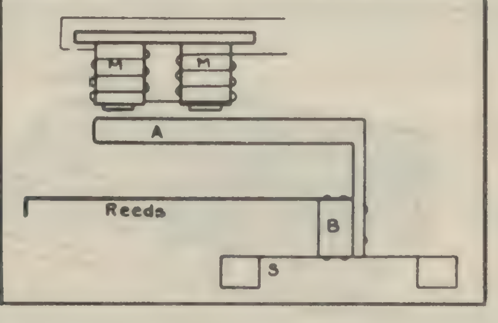
The reeds of the frequency meter can be made to vibrate at different frequencies either by making them of slightly different thicknesses or by weighing the ends very accurately with small amounts of lead. In this manner they are graduated from one end of the instrument to the other, so that the reeds on one end have a lower rate of vibration, and as they progress toward the other end each one has a slightly higher rate of vibration.

This arrangement will cause one or two of the reeds which have a natural rate of vibration closest to the frequency of the alternating current, to vibrate more than the others do when the magnet coil is energized.

The vibration of most of the reeds will be barely noticeable, because the magnetic impulses do not correspond with their natural frequencies. But the reed which has a natural vibration rate approximately the same as that of the alternating current, will vibrate up and down from 1/8 to 1/4 of an inch or more, and perhaps one reed on each side of it will vibrate a little.

The front ends of the reeds are bent downward in short hooks to make them plainly visible and, when viewing them from the front, the end of the reed which is vibrating will appear longer than the others. Then, by reading on the scale directly under this vibrating reed, the frequency can be determined.

Another meter using this same principle, but of slightly different construction, is shown below. This meter has the reeds attached to a bar, "B", that is mounted on



This sketch shows a side-view of another type of vibrating reed frequency meter. This instrument uses a pair of small electro-magnets to vibrate the armature to which the reeds are attached.

a stiff spring, "S", in such a manner that the whole bar with all of the reeds can be vibrated. There is also an iron armature, "A", attached to this bar and projecting out over the reeds beneath the poles of a pair of electro-magnets, "M".

These magnets are excited by the alternating current, the same as the large magnet shown in the previous illustration, and they cause the iron armature to vibrate and rock the bar, thereby causing the reeds to vibrate also.

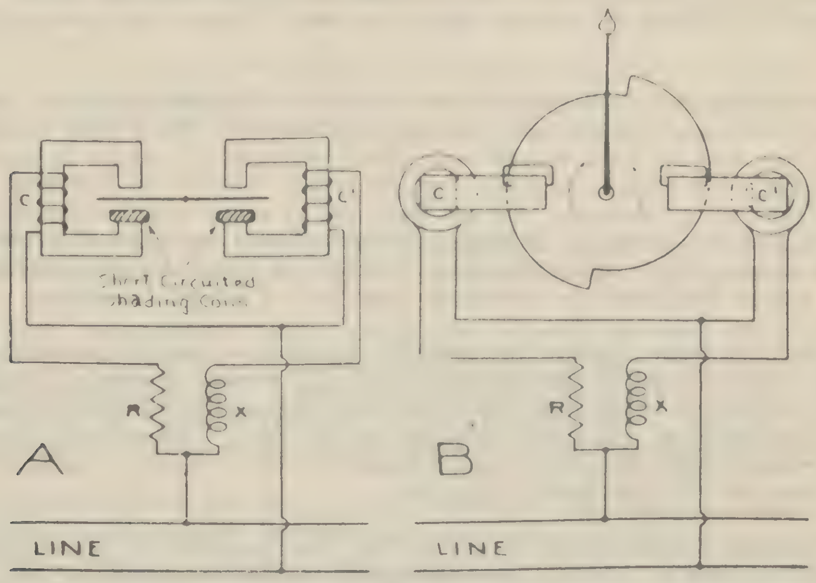
This vibration of the reeds will be hardly noticeable, except on those that have a natural rate of vibration the same as the speed of the bar movement and the frequency of the alternating current which excites the magnets. These several reeds will vibrate so that their ends will be plainly noticeable, as previously explained.

This type of frequency meter has an adjusting screw for varying the distance between the electro-magnets and the armature "A". By changing this adjustment, the amount of vibration of the reeds can be regulated.

If the circuit to which a meter of this type is connected has a frequency of 60 cycles, the reed directly above the number 60 on the scale will be the one which vibrates the most.

This reed, however, will be moving at the rate of 120 vibrations per second, or once for each alternation of the 60 cycles.

INDUCTION-TYPE FREQUENCY METERS - The induction-type frequency meter is more commonly used than the vibrating-reed type. This meter operates on the induction-disk and shaded-pole principle, similar to that which was explained for induction voltmeters and ammeters.



"A" shows a side-view of an induction type frequency meter. This instrument uses the shaded-pole method of producing torque on the disk by induction. "B". Top view of an induction frequency meter, showing the shape and position of the disk between the poles.

The preceding sketch shows a side view of the cores, and disk of an induction-type frequency meter.

In view "A" each of the cores, "C" and "C-1", is wound with exciting coils, one of which is connected in series with a resistor "R", and the other in series with an inductance "X2".

These inductance coils, such as shown at "X", are sometimes called *reactors*. One end or pole of each of the magnet cores is equipped with shading coils, or small, short-circuited coils which are imbedded in one side of the pole faces.

When the coils "C" and "C-1" are excited with alternating current, the flux which is set up in the cores induces secondary currents in the short-circuited shading coils. The flux from these secondary currents in the shading coils, reacts with the flux from the main coils and sets up a shifting flux across the edges of the disk.

This induces eddy currents in the disk and tends to set up torque and rotation of the disk. The position of the shading coils and the shape of the disk can be noted in view "B".

Note, in this view, that the shading coils are placed on the same side of each magnet, so that they will both tend to exert opposing forces on the disk, each trying to revolve the disk in the opposite direction.

When the instrument is connected to a circuit of normal frequency, or 60 cycles, the current flow through each of the coils "C" and "C-1" will be balanced as shown.

You will recall that the inductive reactance of any coil varies in proportion to the frequency. Therefore, if the frequency of the line increases or decreases, it will vary the amount of current which can pass through the inductance "X" and the coil "C-1".

If the frequency is increased, the inductive reactance of coil "X" will become greater and decrease the current through coil "C-1". This will weaken the torque exerted on the disk by this magnet and allow the disk to rotate a small distance to the right.

If the line frequency is decreased below normal, the inductive reactance of the coil "X" becomes less, allowing more current to flow and strengthen coil "C-1". This will cause the disk to rotate to the left a short distance.

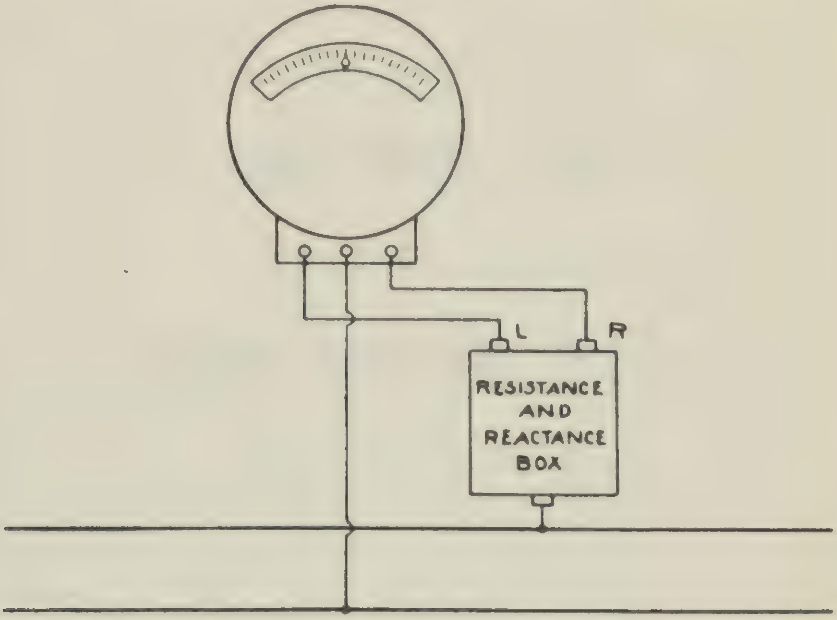
If the disk were perfectly round it would continue to rotate; but it is so shaped that the side under the poles of coil "C" always presents the same amount of surface to the pole, while the side under the poles of coil "C-1" presents a smaller area to the pole as the disk revolves to the left. Therefore, it will turn only a short distance until the increased strength of coil "C-1" is again balanced by the decreased area of the disk under this pole.

The reverse action takes place as the disk rotates to the right, so it will always come to rest at a point corresponding to the frequency of the line to which the meter is connected. The current through coil "C" remains practically constant, because it is in series with the resistor, and the impedance of this non-inductive resistor does not vary with the changes in frequency.

Instruments of this type will operate satisfactorily on voltages either 25% below or above normal. When used on 110-volt circuits, these meters are usually

connected directly across the line, the same as a voltmeter.

The illustration below shows the connections of a frequency meter of this type, with its resistance and reactance units which are enclosed in one box. There are three terminals on the meter and three on the resistance and reactance unit.



This sketch shows the connections for a frequency meter and the resistance and reactance box which is used with the meter.

The terminal "R" of the reactance box is connected to the right-hand terminal of the meter, while the terminal "L" from the box connects to the left-hand terminal of the meter. The center terminal of the meter connects to the line wire opposite to that to which the common wire of the reactance box is connected.

Sometimes these meters fail to register properly because of no voltage or very low voltage on the circuit, or because the moving element has become stuck. If the meter reads extremely high, it may be caused by a bent disk, a short-circuit in the resistance coil, or an open circuit in the reactor coil. Testing with a voltmeter will locate either of these faults in the resistance and reactance box.

If the meter reads too low, it may be due to the moving element having become stuck, or to an open circuit in the resistance unit. If the meter reads opposite to what it should, that is, if the needle indicates a lower frequency when you know the frequency is increased, or if it indicates a higher frequency when the line frequency is decreased, then the two outside terminals at the meter or at the reactance box should be reversed.

SECTION VIII

TEST METER DATA

MODEL 215 AND MODEL 260 AC-DC VOLT OHM MILLIAMMETER OPERATING INSTRUCTIONS

1. GENERAL - The Model 215 or the Model 260 Test Unit is a small, compact and complete instrument with high sensitivity for testing and locating trouble in all types of circuits. The large four and one half inch meter provides a long scale that is easy to read and the compact arrangement of the control units allows the overall size of the bakelite housing to be comparatively small for maximum portability.

The electrical circuit is designed to give maximum insurance against inaccuracy and damage to the component parts. Impregnated cable wiring is used throughout. The high grade copper-oxide rectifier for A.C. measurements is individually calibrated with a precision wire wound shunt and multiplier. All metallized resistors are matched in pairs to close tolerance for accuracy and are firmly held in place on a special bakelite plate machined for this purpose. The entire assembly is truly rugged and can well withstand the wear and tear of the service work for which it is designed.

2. DC VOLTS - Place the DC-AC-Output switch in the D.C. position. Rotate the range selector switch to any of the five ranges required. Plug the test leads in the two jacks marked "POS." and "NEG.", inserting the red lead in the red or "POS." jack and the black lead in the black or "NEG." jack. This applies to the checking of all ranges with the exception of the 5,000 volt range. For the checking of the 5,000 volt range set the selector switch at the 1000 V position and insert the red lead in the 5,000 V.D.C. jack and the black lead in the "NEG." jack. Read the voltage on the black second top arc on the scale marked D.C. For the 2.5 volt range, use the 0 to 250 figures and divide by 100. For the 1,000 volt range, use the 0 to 10 figures and multiply by 100. For the 5,000 volt range, use the 0 to 50 figures and multiply by 100.

CAUTION: Due to danger always present when testing high voltages we recommend that the leads be clipped on and the connections made before turning on the power supply.

3. A.C. VOLTS - Place the DC-AC-OUTPUT switch in the A.C. position. Rotate the range selector switch to any of the five ranges required. Plug the test leads in the two jacks marked "POS." and "NEG.", inserting the red lead in the red or "POS." jack and the black lead in the black or "NEG." jack. This applies to the checking of all ranges with the exception of the 5,000 volt range. For the checking of the 5,000 volt range set the selector switch at the 1,000 V position and insert the red lead in the 5,000 V.A.C. jack and the black lead in the "NEG." jack. Read the voltage for the 2.5 volt range on the lower red arc marked "2.5 V.A.C. only." For the other ranges use the upper red arc marked A.C. For the 1,000 volt range, use the 0 to 10 figures and multiply by 100. For the 5,000 volt range, use the 0 to 50 figures and multiply by 100.

CAUTION: Due to the danger always present when testing high voltages we recommend that the leads be clipped on and the connections made before turning on the power supply.

4. OUTPUT METER - Make connections as for measuring A.C. volts in 3, except place the DC-AC-OUTPUT switch in the OUTPUT position. A condenser is connected in series with this switch for blocking out the D.C. component when connections are made directly at the plate.

5. D.C. MILLIAMMETER - Place the DC-AC-OUTPUT switch in the D.C. position. Rotate the range selector switch to any of the four ranges required. Plug the test leads in the two jacks marked "POS." and "NEG.", inserting the red lead in the red or "POS." jack and the black lead in the black or "NEG." jack. Read the current on the black second top arc on the scale marked D.C. For the 500 M.A. range use the 0 to 50 figures and multiply by 10. For MODEL 260, read the 100 MICROAMPERES on the 0 to 10 figures and multiply by 10.

6. OHMS - Place the DC-AC-OUTPUT switch in the D.C. position. Rotate the range selector switch to any of the three ranges required. Plug the test leads in the two jacks marked "POS." and "NEG." Short the test leads and set the pointer to "0" by rotating the ZERO OHMS knob. Read ohms on the top arc using the multiplying factor indicated by the switch position.

7. DECIBELS - Power level indicators find their greatest application in P.A. and telephone work. It is difficult to use them in testing a radio set since the loads are variable and constant impedance transformers would have to be substituted in the output circuit. For radio service work the output meter described in 4 is generally used. The output meter can be used across different loads and a reference chart used to convert the readings in volts to power level in decibels.

The most commonly used reference level of .006 watt in a load of 500 ohms impedance is the basic calibration of the D.B. meter in the Model 215. When a .006 watt signal is dissipated in a load of 500 ohms, a voltage of 1.73 volts is developed across the load and it is at this point on the dial that the zero is placed.

Set the DC-AC-OUTPUT switch in the A.C. position. Rotate the range selector switch to any of the five ranges required. Plug the test leads in the two jacks marked "POS." and "NEG." Read decibels on the black arc at the bottom of the scale marked D.B. When reading decibels, add algebraically to the scale indications the number indicated at setting of the range selector switch. For example, if the scale indication is -4DB with the switch at +12DB, the true reading will be +8DB.

8. BATTERIES - A Burgess No. 1 uni-cell of 1.5 volts and two Burgess No. 422 batteries of 3 volts are mounted inside the tester for ohmeter measurements. When it is no longer possible to bring the pointer to "0" on the R and Rx100 ohm ranges with the test leads shorted, the 1.5 volt battery should be replaced. If this adjustment is no longer possible on the Model 215, Rx1000 or Model 260, Rx10,000 scale, the two 3 volt batteries should be replaced. To replace the batteries, remove the four corner panel screws and lift the complete panel out of the case.

SECTION IX

METERS USED ON X-RAY CONTROLS

THE MILLIAMMETER - On most x-ray apparatus, the milliammeter is connected in the ground mid-secondary circuit which enables the meter to be safely placed in the grounded control.

The milliammeters used in the grounded mid-secondary circuits are of two types. On all self-rectified machines the milliammeter must be a D.C. meter. Here, the current flows through the high tension secondary winding in only one direction, because of the half wave rectification brought about by either the valve tube or the x-ray tube. On four valve, full wave rectification, the current in the high tension secondary circuit flows alternately in one direction, and then in the other direction so either an A.C. milliammeter or a D.C. meter may be used. When using the D.C. meter the A.C. from the transformer must be rectified.

A D.C. milliammeter in the grounded control circuit will read the same value as a D.C. milliammeter placed in the high tension secondary circuit in series with the anode of the x-ray tube, and is unaffected by changes in kilovoltage or length and size of shockproof high tension cables. An A.C. milliammeter reads not only the current flowing through the x-ray tube, but also the A.C. capacity current flowing through the transformer winding. This total current will change with kilovoltage and with the length and size of any shockproof cable or aerial system used in a high tension circuit even though the milliamperage through the x-ray tube is held absolutely constant. This additional current is caused by the additional capacity of the high tension system.

Therefore, an A.C. milliammeter is never absolutely accurate when used in the control stand. The charging current or the additional current recorded by the meter over and above the actual x-ray tube current may vary anywhere from 1 to 15 M.A. or more, depending on the circumstances. Usually it is in the neighborhood of 4 to 6 M.A. at 80 P. Kv. If the machine is to be used for fluoroscopy or superficial therapy at milliamperages from 3 to 6, this A.C. milliammeter should not be relied upon to give accurate milliamperage indications at these low values. For milliamperage values of 50 or above, the percentage of inaccuracy becomes relatively small if the milliamperage values increase. This has been the main reason for designing many A.C. milliammeter scales so that milliamperage values below 10 or 15 could not be read.

D.C. MILLIAMPEREMETERS USED ON X-RAY APPARATUS - With the development of entirely shockproof apparatus, a meter in the high tension circuit became impractical; therefore, means of installing an M.A. meter in the control became necessary.

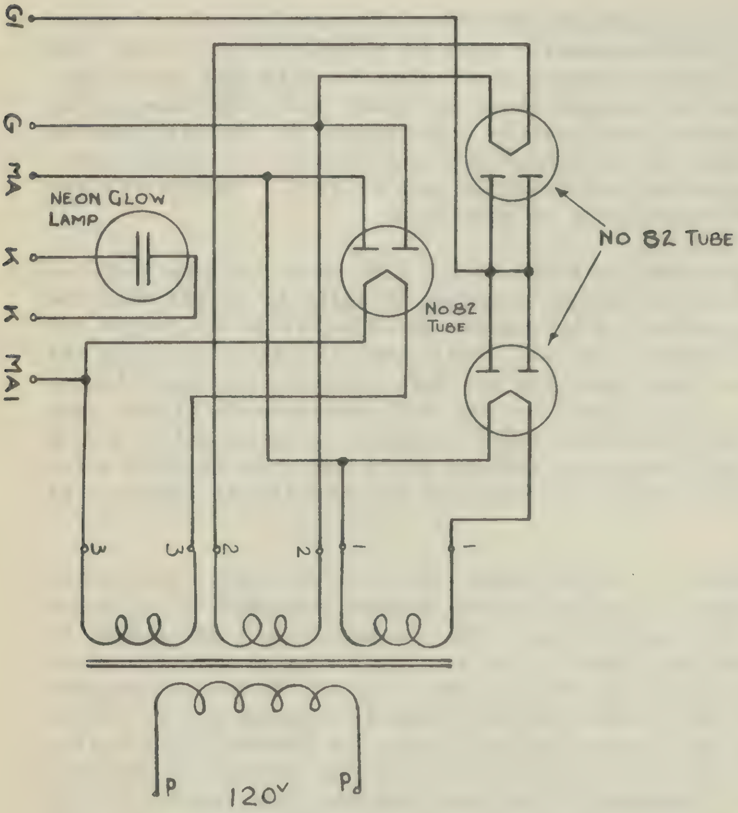
A D.C. meter can be utilized by means of a rectifying tube or copper oxide rectifier which converts the A.C. from the M.A. terminals of the high tension transformer to D.C.

Many full wave generators employ a D.C. M.A. meter utilizing a rectifying tube. All these units are furnished with instructions for the M.A. meter rectifier. A schematic drawing of a tube type rectifier (Westinghouse #3-D-9072) appears hereafter.

The unit consists of a small transformer having a 120 volt primary and three 2.5 volt secondaries to supply filament voltage for the #82 tubes. Three type #82 tubes, which are mercury vapor full wave rectifiers, are also included. This type tube has a common filament and two separate and distinct anodes.

A glow lamp (K-K) is connected in series with one side of the M.A. meter (low scale only) to eliminate a small filament to plate leakage. This leakage is so

slight that the glow lamp is only in the low scale circuit of the meter. On the higher scale readings the above mentioned filament to plate leakage of the rectifier tubes is negligible.



3-D-9072

On most apparatus utilizing this type of meter, the hookup of the meter rectifier to the x-ray apparatus is as follows: The M.A. and G connections of the transformer connect directly to the M.A. and G of the meter rectifier. The M.A. meter is in series with a connection between G1 and M.A. 1. On the low scale of the meter the glow lamp is also in series with this connection.

The high scale meter terminals are generally connected through relay contacts directly to the meter rectifier in such a way that the glow lamp (K-K) is out of the circuit entirely.

COPPER OXIDE TYPE - Some models of meter rectifiers employ a copper oxide rectifier to change the current from the transformer from A.C. to D.C. The principle of operation is essentially the same as when rectifier tubes are employed. Since the copper oxide rectifier will allow the current to flow in one direction only, it effectively changes an A.C. voltage to D.C. There is no filament to plate leakage with copper oxide rectifiers, thus the need of the glow lamp in the low scale is unnecessary.

MILLIAMPERE SECOND METERS - For milliamperages above 100, the exposure times generally used are quite often too short to obtain an accurate milliamperage reading with the conventional meter. Even for test exposures at high milliamperages, the x-ray tube may be dangerously overloaded in an attempt to obtain an accurate milliamperage reading.

For this reason it is necessary to use milliampere second meters which are often called Ballistic milliammeters. These meters may be used at the shorter time intervals usually below 1/2 second. These meters are made with a heavy moving element which has a relatively high moment of inertia so that the meter needle swings up slowly during and after the exposure. The meter is read at its maximum point of swing and gives a reading directly in milliampere seconds. This meter utilizes a D.C. meter movement so that the scale may be evenly proportioned in order that it will be unaffected by using different exposure times for the same milliamperage.

The scales on the milliampere second meters in the past have been 0-50, 0-100 M.A. when single scale instruments have been used, and 0-25 to 0-125 M.A. when double scale instruments have been used. These scales cover the majority of applications.

THE VOLTMETER OR KILOVOLT METER - Until comparatively recently the voltmeter used on x-ray apparatus was a standard A.C. voltmeter usually reading from 0-250 volts and was either a single scale or double scale type. When the machine was installed, it was calibrated by means of a sphere gap and ballistic milliammeter and a series of charts plotted with the primary voltage and kilovoltage and various milliamperages.

This method of calibration is fairly accurate on a constant voltage line, and has been widely used by practically all x-ray manufacturers. The voltmeter could then be referred to and from the calibration charts a pre-reading voltage setting could be made.

A different method of voltmeter calibration is used in conjunction with a so-called line voltage compensator. The voltmeter scale has calibration points marked for various milliamperages at different points on the scale. The kilovoltage selector controls were supposedly direct reading. If the line voltage compensator is adjusted so that the voltmeter needle coincides with the correct milliamperage setting, the same milliamperage is obtained on the milliammeter. This system is fairly satisfactory on a low milliamperage unit such as a mobile unit, but on higher milliamperage units the calibration is not very accurate. It can be made accurate only through a small kilovoltage range because the line voltage drop varies considerably with kilovoltage for the same milliamperage. Therefore, the resulting kilovoltage may vary considerably from the dial settings at low and high milliamperages. Usually the machine is made accurate for high milliamperages at the usual operating kilovoltages, between 60 and 80. It follows then, that the actual kilovoltage is usually slightly higher than the kilovoltage setting at the low end of the scale, and lower at the high end of the scale.

An improvement in this method has been made by having the voltmeter calibrated directly in load reading P. Kv. for the various milliamperages. This, however, necessitates a different scale for each milliamperage used and because of the load limitations on x-ray tubes, it is not considered practical to use this system at milliamperages above 30 by reason of limited ratings, particularly on self rectified equipment.

THE PRE-READING FILAMENT METER - The modern tendency in x-ray machine design is to completely shockproof the entire machine, eliminating all exposed high tension.

Formerly it was common practice to have a relatively large A.C. ammeter in series with the x-ray tube filament in the aerial system. In addition to this an A.C. ammeter was often used in the x-ray filament primary circuit in the control stand. Now that aerial systems are obsolete, it is necessary to rely on the A.C. ammeters in the filament primary circuit for the correct setting of the x-ray filament temperature.

The A.C. ammeter used in the filament primary circuit has an inherent difficulty. The actual filament amperage through the average x-ray tube in changes of from 100 M.A. to 200 M.A. is usually less than 1/2 ampere. Since this current in the x-ray tube circuit is at a low voltage (approximately 10 volts), it is readily seen that the current in the x-ray filament primary circuit, which is at a considerably higher voltage -- usually from 80 to 120 is proportionately less. When the

conventional meter is used, therefore, it is difficult to accurately set the desired milliamperage values, due to the limited scale range of the filament meter.

This situation has been considerably improved by using a suppressed zero type meter so that instead of having the meter reading from 0-1 ampere, the meter reads from .5 to 1 ampere. This effectively doubles the scale length and makes the meter easier to read. There is a limit however, to the amount of suppression that can be applied to a meter of this type. The meter manufacturers explain that more suppression makes the meter inconsistent because the spring tension on the meter needle causes it to bounce too hard against the lower limit stop, when the current ceases to flow. Furthermore, there is no means of adjusting the zero point on this type meter; therefore, inaccuracies and changes in reading for the same actual current flow are apt to occur.

The use of a voltmeter for a pre-reading x-ray filament meter does not improve this situation because the change in scale length from one amperage to another is no greater.

The use of a larger size ammeter will, of course, effectively increase the scale length of the meter and will therefore increase the accuracy with which the meter can be set and read.

SECTION X

WIRE CALCULATIONS

WIRE CALCULATIONS

Information on the size of copper wires, their resistance, and current carrying capacity can be obtained from the tables on the following pages. These tables should be used whenever possible.

Frequently, tables are not available or do not give the needed information. A knowledge of simple wire calculations is important.

For example, the table in the National Code which gives the allowable current carrying capacities is based on the heating of the wires and does not consider voltage drop due to resistance of long runs or lines. Both of these considerations are very important and should always be kept in mind when planning any electrical wiring system.

The wires must not be allowed to heat enough to damage their insulation, or to a point where there will be any chance of igniting nearby materials. If wires are allowed to heat excessively, it may cause the solder at joints to soften and destroy the quality of the splices; and in other cases it may result in expansion of the wires and consequent damage. Heat is also objectionable because it increases the resistance of the wires, thereby increasing the voltage drop for any given load.

VOLTAGE DROP - Whether or not the wires heat noticeably, the resistance and voltage drop may be great enough to interfere seriously with the efficient operation of equipment.

It is very important to have all wires of the proper size, to avoid excessive heating and voltage drop; and in the case of long runs, it is necessary to determine the wire size by a consideration of resistance and voltage drop, rather than by the heating effects.

To solve the ordinary problem requires a knowledge of a few simple facts about the areas and resistance of copper conductors and the application of simple arithmetic.

Wire sizes are commonly specified in B & S gauge numbers. This system was originated by the Brown & Sharpe Company, well known manufacturers of machine tools. The B & S gauge is commonly called the American Wire Gauge, and is standard in the United States for all round solid electrical wires.

These gauge numbers are arranged according to the resistance of the wires, the larger numbers being for the wires of greatest resistance and smallest area. This is a great convenience, and a good rule to remember is that decreasing the gauge by three numbers gives a wire of approximately twice the area and half the resistance. As an example--if we increase the gauge from No. 3, which has .1931 Ohms per 1000 ft., to No. 6, we find it has .3872 Ohms per 1000 ft., or almost double.

Brown & Sharpe gauge numbers range from 0000 (four aught), down in size to number 44. The 0000 wire is nearly 1/2 inch in diameter and the number 44 is as fine as a small hair.

The most common sizes used for light and power wiring are from 0000 down to No. 14. The No. 16 and No. 18 wires are commonly used for control or auxiliary circuits only.

The Mil is a very convenient unit for measuring the diameter and area of the wires. A mil is equal to 1/1000 of an inch. It is small enough to measure and express sizes very accurately. Thus, a wire of 250 mils diameter is also .250", or 1/4 inch in diameter.

As the resistance and current-carrying capacity of conductors both depend on their cross-sectional area, we must also have convenient small units for expressing this area. For square conductors such as bus bars, the Square Mil is used. This is simply a square, 1/1000 of an inch. For round conductors we use the Circular Mil, which is the area of a circle with a diameter of 1/1000 of an inch. The abbreviation commonly used for circular mil is C.M.

To determine the area of a round conductor in Circular Mils, square the diameter in mils or thousandths of an inch. (To square a number, multiply it by itself.)

Stranded conductors are used on all sizes larger than 0000. As stranded conductors are not solid throughout, we cannot determine their area accurately by squaring their diameter. This diameter also varies somewhat with the twist or "lay" of the strands.

To determine the cross-sectional area of such conductors, determine the area of each strand, either from a wire table or by calculation from its diameter, and multiply this by the number of strands, to get the total area of the cable in C.M.

The following wire table gives some very convenient data and information on the common sizes of conductors, and will be very convenient for future reference.

RESISTANCE OF CONDUCTORS - It is often necessary to determine the exact resistance of a conductor of a certain length in order to calculate the voltage drop it will have at a certain current load.

The resistance per 1000 ft. of various wires can be obtained from the wire table, and from these figures it is easy to calculate the resistance of smaller or greater lengths.

For example, to find the total resistance of a two-wire run of No. 10 conductors, 150 ft. long. First multiply by 2, to get the entire length of both wires, or 2 x 150 equals 300 feet. Referring to the wire table we find that the resistance of No. 10 wire is .9792 Ohms per 1000 ft. Since the circuit in question is less than 1000 ft. in length, or 300/1000, multiplied by .9792. This give a total of .29376 Ohms; or approximately .29, which would be accurate enough.

In another case, assume a line using number 1 wire between two points 1650 feet apart. To determine the total resistance, multiply the length of the wire by 2 to determine the entire length of the wires. This equals 3300 feet. The wire table reveals that the resistance of No. 1 wire is .1215 Ohms per 1000 ft. Then as 3300 ft. is 3.3 times 1000, multiply 3.3 by .1215. This equals .40095 or approximately .4 Ohms.

The National Code table for carrying capacities of wires, allows 91 amperes for No. 1 R. C. (rubber covered) wire. With this amount of current flowing through the line, the voltage drop will be I x R or 91 x .4 = 36.4 volts. This drop is too great to be practical. If, under these conditions, 120 volts were applied to one end of the line, the devices at the other end would receive only 120-36.4, or 83.6 volts. The watts loss in the line would be I x Ed, or 91 x 36.4 = 3,312.4 watts, or 3.31 KW.

The practical load for such a line would be about 25 Amperes, which would give a voltage drop of 25 x .4 or 10 volts. If 120 volts are applied to the line, the equipment will receive 110 volts, and the loss will only be 25 x 10 or 250 watts.

In many cases it may be necessary to calculate the resistance of a certain length of wire of a given size.

This can be done very easily if the unit resistance of copper is known. The unit used is called the Mil Foot. This represents a piece of wire 1 mil in diameter and 1 ft. in length, and is a small enough unit to be very accurate for all practical calculations. A round wire of 1 mil diameter has an area of just 1 circular mil, as the diameter multiplied by itself or "squared", is 1 x 1 = 1 circular mil area.

The resistance of ordinary copper is 10.79 Ohms per Mil Foot, but the figure 10.8 is generally used. This figure or "constant" is important and should be remembered.

Assume the resistance of a piece of No. 12 wire, 50 ft. long, is to be determined. It is known that the resistance of any conductor increases as its length increases, and decreases as its area increases. Thus, to determine the resistance for a No. 12 wire 50 ft. long, multiply 50 x 10.8, or 540 Ohms. Referring to the table, it is observed that the area of a No. 12 wire is 6530 C.M., which will reduce the resistance in proportion. Thus, by division, 540 ÷ 6530 = .0826 Ohms.

In another example, find the resistance of 3000 ft., of No. 20 wire. Thus, 3,000 multiplied by 10.8 equals 32,400; and, as the area of No. 20 wire is 1022 C.M., dividing 32,400 ÷ 1022 = 31.7 Ohms.

Checking this with the table, the table shows a resistance of 10.14 Ohms per 1000 ft. for No. 20 wire. Therefore, for 3000 ft. multiply 3 x 10.14 = 30.42 Ohms. The small difference in this figure and the one obtained by the first calculation, is caused by using approximate figures instead of lengthy complete fractions.

The table gives the allowable current carrying capacities of wires with rubber insulation; also those with varnished cloth and other insulations, such as slow burning, etc.

VOLTAGE DROP-X-RAY INSTALLATIONS - It must be remembered that this table does not take into consideration the length of the wires or voltage drop. For this reason it may be wise to use larger wires than the table suggests.

In X-Ray installations, for example, it is desirable to have a minimum voltage drop, as voltage drop, under load conditions will be reflected in radiographic results. Too small a wire size will lead to inconsistent radiographs and tend to make an accurate calibration of X-Ray apparatus almost impossible.

The percentage of voltage drop on an installation is controlled by conditions such as, the power supply available, the length of run, and also the conductor material available. If recommending the size of a power transformer, generator, and conductors to be used for the length of run from the power source, the following will be found useful. It will permit the use of current carrying conductors which will have a predetermined amount of voltage drop for any given load. A voltage drop of 2% is average, adrop greater than 3% of the incoming line voltage is undesirable.

SIMPLE FORMULA FOR CONDUCTOR AREA - For selecting the proper size of conductor for any known load in amperes, and to keep the voltage drop within the desired practical limit, the use of the following simple formula will aid in the determination of the circular mil area of the conductor to use.

The resistance of copper, the total length of the line, and the current load in Amperes must be considered. The formula:

$$C.M. = \frac{10.8 \times L \times 2 \times I}{Ed}$$

In which:

C.M. = Circular mil area of conductor.
10.8 = Resistance of copper per mil foot.
L = Length of line in feet.
2 = Multiply by, to obtain total length of both wires.
I = Load in amperes.
Ed = Allowable voltage drop in volts. (Not in percent)

Assume it is desired to run a feeder 200 ft. long to a fuse box to which only a self-rectified X-Ray unit capable of delivering 50 M.A. at 85 K.V. is connected. The line load will be approximately 50 amperes. (In x-ray work it is estimated that for every milliampere on self-rectified equipment and two milliamperes on full wave equipment, one ampere of current must be available.)

Allowing a 6 volts drop on the feeders, and, using the wire size formula, substitute the known values as follows:

$$C.M. = \frac{10.8 \times 200 \times 2 \times 50 = 36,000 \text{ C.M.}}{6}$$

Referring to the table, observe that the next size larger is No. 4 wire, which has 41,740 C.M. area. The code table allows 70 amperes for this wire with rubber insulation. Thus, it will be safe to use No. 4 wire under these conditions.

VOLTAGE DROP FORMULA - To determine the voltage drop on an installation, already made, or on the proposed wires for a layout, simply transpose the above formula, interchanging voltage drop for C.M. area, as follows:

$$Ed = \frac{10.8 \times L \times 2 \times I}{C.M.}$$

Imagine a two-wire, 110 volt installation where the load is 25 amperes and the feeder is 120 feet long.

The Code recommends the use of a No. 10 wire for 25 amperes, and the area of No. 10 wire is 10,380 C.M. Then, substituting these values in the formula.

$$Ed = \frac{10.8 \times 120 \times 2 \times 25}{10,380}$$ or 6.24 volts, whereas the drop should not exceed more than 3% of 110, or about 3.3 volts drop.

It is very important to be able to do these simple wire calculations on all installations.

CURRENT CARRYING CAPACITY IN AMPERES

Size B & S Gauge	Diameter in Mils	Area in Circular Mils	Resistance (Ohms) per 1000 feet at 60° F.	Allowable Current in Amperes: Rubber Insulation	Allowable Current in Amperes: Asbestos Insulation
		Solid Wire			
26	15.94	254.1	40.75		
25	17.90	320.4	32.21		
24	20.10	404.01	25.60		
23	22.57	509.5	20.30		
22	25.35	642.4	16.12		
21	28.46	810.1	12.78		
20	31.96	1022.	10.14		
19	35.89	1288.	8.04		
		Solid or Stranded			
18	40.30	1624.	6.374	3	5
16	50.82	2583.	3.936	6	10
14	64.08	4107.	2.475	15	32
12	80.81	6530.	1.557	20	42
10	101.9	10380.	.9792	25	54
9	114.4	13090.	.7765		
8	128.5	16510.	.6158	35	71
7	144.3	20820.	.4883		
6	162.	26250.	.3872	45	95
5	181.9	33100.	.3071	52	110
4	204.3	41740.	.2436	60	122
3	229.4	52640.	.1931	69	145
2	257.6	66370.	.1532	80	163
1	289.3	83690.	.1215	91	188
0	324.9	105500.	.09633	105	223
00	364.8	133100.	.07639	120	249
000	409.6	167800.	.06058	138	284
0000	460.	211600.	.04804	160	340

WIRE CALCULATIONS

Size of Conductor	1	2	3	4	5	6	7	8	9	
	No. of Conductors in One Conduit									
18	½	½	½	½	½	½	½	½	¾	To be used in auxiliary control circuits only.
16	½	½	½	½	½	½	¾	¾	¾	
14	½	½	½	½	¾	¾	¾	1	1	
12	½	½	½	¾	¾	1	1	1	1¼	
10	½	¾	¾	¾	1	1	1¼	1¼	1¼	
8	½	¾	1	1	1¼	1¼	1¼	1¼	1½	
6	½	1	1¼	1¼	1½	1½	2	2	2	
5	¾	1¼	1¼	1¼	1½	2	2	2	2	
4	¾	1¼	1¼	1½	2	2	2	2	2½	
3	¾	1¼	1¼	1½	2	2	2	2½	2½	
2	¾	1¼	1½	1½	2	2	2½	2½	2½	
1	¾	1½	1½	2	2	2½	2½	3	3	
0	1	1½	2	2	2½	2½	3	3	3	
00	1	2	2	2½	2½	3	3	3	3½	
000	1	2	2	2½	3	3	3	3½	3½	
0000	1¼	2	2½	2½	3	3	3½	3½	4	

POWER SUPPLY REQUIREMENTS AND WIRE DATA - The following was compiled as a guide for determining the correct size of the following; fuse box, and power transformer or generator needed to operate various types of X-Ray apparatus. All units shown on this listing may be encountered at various army installations. This complete listing represents the recommendations of the National Electrical Manufacturing Association.

POWER SUPPLY REQUIREMENTS

CLASSIFICATION	CAT. NO. OR DESCRIPTION	OUTPUT MA.	OUTPUT KV.	NOMINAL LINE VOLTAGE	RECOMMENDED TRANSF (KVA)	SIZE WIRE (B&S) FROM TRANSF. TO LINE SWITCH	SIZE WIRE (B&S) FROM LINE SWITCH TO CONTROL	GROUND WIRE	FUSE SIZE (AMPS)	LINE SWITCH (AMPS.)
Self-Rectified							(See note #6)			
R & F - 10 ma	-	10	85	115	1.5	8	Supplied (#12)	8	15	Base Recept.
				230	1.5	12	" - "	8	10	" "
R & F - 30 ma	-	30	85	115	5	6	" - "	8	40	60
				230	5	10	" - "	8	25	30
Dental- 10 ma	-	10	-	115	1.5	10	" - (#14)	8	15	Base Recept.
Port.&Mobile-15 ma	-	15	75	115	3	6	" - (#12)	8	30	H.D.Base "
				230	3	10	" - "	8	15	" " "
Port.&Mobile-30ma	-	30	80	115	5	6	" - "	8	50	60
				230	5	10	" - "	8	30	60
F. & R.-50-60 ma	-	50-60	85	230	10	6	10	8	50	60
F. & R.-100 ma	-	100	85	230	15	4	6	8	70	100
Half Wave (1 Valve)										
F. & R. - 100 ma	-	100	100	230	15	2	4	8	80	100
Half Wave (2 Valve)										
Lt. Ther.-100kv.		10	100	115	3	6	-	8	20	30
				230	3	10	-	8	10	30
Lt. Ther.-140kv.	-	10	140	115	3	6	-	8	25	30
				230	3	10	-	8	15	30
Full Wave (4 Valve)										
F. & R.-200 ma	-	200	100	230	15	4	6	8	70	100
F. & R.-300 ma	-	300	100	230	25	1	4	8	120	200
F. & R.-500 ma	-	500	100	230	37.5	00	3	6	180	200
F. & R.-1000 ma	-	1000	100	230	50	300000	0	4	350	400
Three Phase										
F. & R.-500 ma	-	500	100	230	3 - 15	3	4	8	100	200
F. & R.-1000 ma	-	1000	100	230	3 - 25	00	3	6	200	200
Deep Therapy										
Villard-15 ma	-	15	200	230	5	8	-	8	30	30
Villard-30 ma	-	20	220	230	7.5	8	-	8	40	60
Const. Potential	-	15	220	230	10	6	-	8	50	60
Self-Cont.-5-10 ma	-	10	200	230	15	6	-	8	60	60
Self-Cont.-15 ma	-	15	220	230	15	4	-	8	60	60
400 kv.	-	5	400	230	15	6	-	8	60	60

NOTES

1. The above specifications are the minimum requirements for a single x-ray machine of the rating specified.

2. They are based on a normal line regulation of 2% when the x-ray machine is not in operation.

3. The wire sizes under column "Size Wire From Transformer to Line Switch" are based on a run of 100 ft. If the run is 200 ft., double the wire size.

4. The wire sizes under column "Size Wire From Line Switch to Control" are based on a maximum run of 10 ft.

5. If more than one x-ray machine is to be used, or additional load is contemplated for the future, larger wire and power transformer sizes or power generator must be specified for satisfactory operation.

6. Incoming line cable supplied by manufacturer.

7. R & F on above chart R. Radiography F. Fluoroscopy.

SECTION XI

NOTES ON BLUEPRINT READING

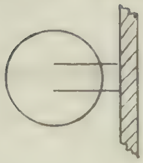
NOTES ON BLUEPRINT READING

The basic x-ray machine utilizes several circuits. A simple unit has, for example:

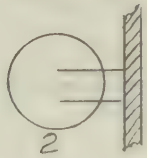
1. The high tension transformer primary circuit comprising of:
    - a. Incoming line.
    - b. Fuses
    - c. Main Switch
    - d. Auto transformer
    - e. Major K.V.P. selector
    - f. Minor K.V.P. selector
    - g. Voltmeter
    - h. Contactor
    - i. Circuit breaker
    - j. Line compensator
2. The x-ray tube filament circuit (primary) comprising of:
    - a. A winding on the auto transformer.
    - b. Filament control.
        - 1. Inductance type
        - 2. Resistance type
    - c. Frequently a limiting device with a switch (Fluo. to Rad; or small focal spot to large)
        - 1. R.F. Switch on Field Unit
        - 2. Some tubes have throw switch (GE non S/P)
    - d. Filament meter (for pre-reading value)
    - e. Adjustment tap on auto transformer to aid in regulation of primary settings.
3. The operating circuits frequently contain many safety circuits. These are additional however to the basic operating circuit. A basic circuit would contain:
    - a. An exposure switch.
        - 1. Hand Timer.
        - 2. Foot Switch.
    - b. Circuit breaker
    - c. Contactor.
4. A milliampere meter circuit usually contains a double scale M.A. meter the proper scale of which is selected by means of an auxiliary switch.
    - a. This circuit is usually from one side of the split high tension mid-secondary to the M.A. meter, to the opposite grounded side of this transformer.
5. The high tension circuit includes:
    - a. The high tension cables from the step up transformer to the x-ray tube.
    - b. The Filament circuit for the x-ray tube.
    - c. The x-ray tube proper.

There are numerous symbols that one must learn to identify as they look at a blueprint. A few of the more important symbols are shown for the purpose of aiding those who may not have a wide experience in this work.

JUNCTION BOX



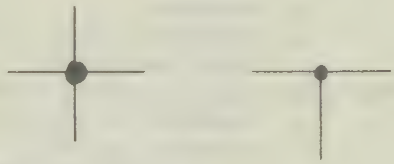
SINGLE
CONVENIENCE OUTLET



DOUBLE
CONVENIENCE OUTLET

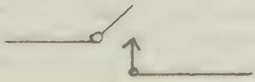
VOLTMETER

CROSSED WIRES

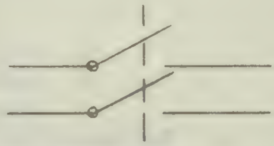


JOINED WIRES

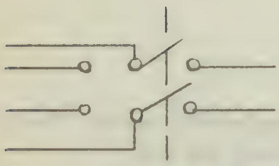
SINGLE POLE SINGLE THROW
SWITCH



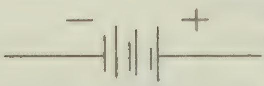
PUSH BUTTON
SWITCH



DOUBLE POLE SINGLE THROW
SWITCH

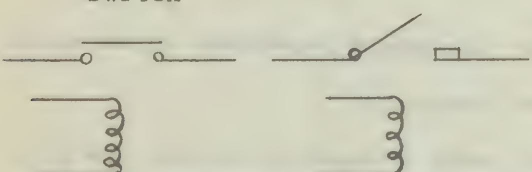


DOUBLE POLE DOUBLE THROW
SWITCH

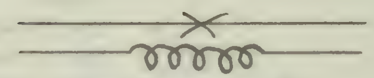


BATTERY

SELECTOR SWITCH

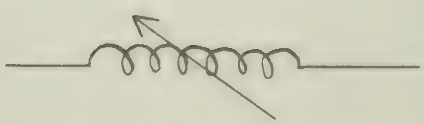


CONTACTORS



CIRCUIT BREAKER

FUSE



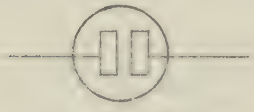
VARIABLE CHOKE COIL

AMMETER

MILLIAMPEREMETER

MILLIAMPERE SECOND METER

MALE PLUG



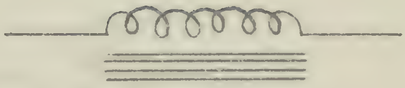
FEMALE PLUG

LAMP

FIXED RESISTOR

ADJUSTABLE RESISTOR

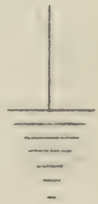
RHEOSTAT



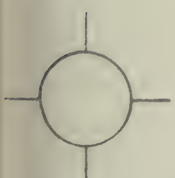
FIXED CHOKE COIL

BINDING POSTS
OR
TERMINAL STUDS

TEST POINTS
OR
ADJUSTABLE LEADS



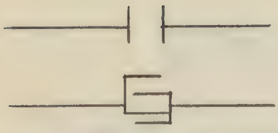
GROUND CONNECTION



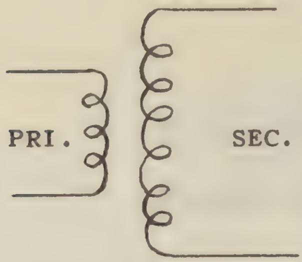
CEILING
OUTLET

FLOOR OUTLET

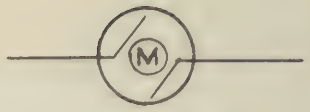
SINGLE CONVENIENCE
OUTLET
DROP CORD



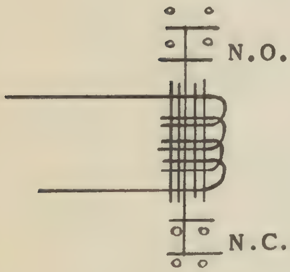
CONDENSERS



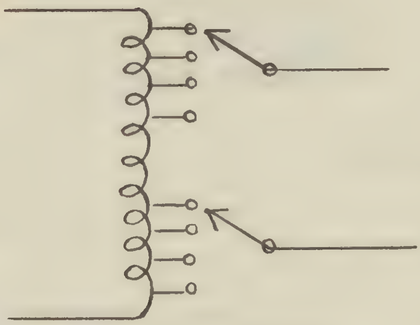
STEP-UP TRANSFORMER



MOTOR

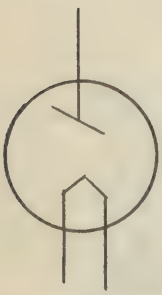


RELAY

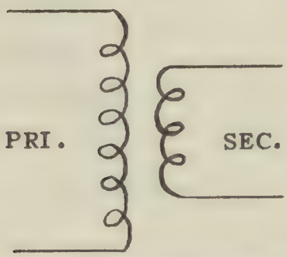


AUTO-TRANSFORMER

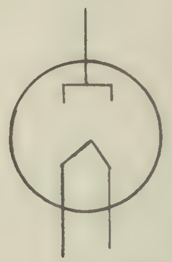
ELECTROMAGNET



X-RAY TUBE



STEP-DOWN TRANSFORMER



VALVE TUBE

SECTION XII

MEDICAL DEPARTMENT SERVICEMAN'S TOOLS - WORKMANSHIP

The satisfactory operation of any piece of equipment depends primarily on two important factors. First, a good and complete installation, and second, periodical inspection for maintenance.

An Army Service man is under obligation to turn equipment over to those charged with its operation in perfect mechanical and electrical condition.

Every effort has been made by the various manufacturers to see that equipment is shipped from their factories in perfect condition. Barring unseen or unusual accidents, Medical Department equipment and materials will be received for installation in A-1 condition.

Every effort is made during this course to acquaint you with procedures for installing and servicing these expensive Medical Department equipments.

It is necessary to learn the essentials of proper installation and service work to prepare you to do this work without loss of time and materials.

The duties of Army Service Men may be considered under three classifications.

1. The installation of equipment.
2. Final inspection, adjustments and instructions to the operator.
3. Periodical Inspection.

It is reasonable to expect that equipment carefully and properly installed will operate better, and will be trouble free longer, than if installed carelessly or hurriedly.

A careful workman will see that equipment is handled in a manner to protect its finish from scratches, abrasions, etc. Medical Department apparatus is expensive. Be proud to display an installation that looks new, and does not show evidence of rough handling.

You may be called upon to make, or arrange, a layout of part, or all of various departments. Available space, location of doors, windows, heating devices, plumbing, electrical outlets, power supply, all must be considered.

IT IS WISE TO ANALYZE A PROBLEM BEFORE ATTEMPTING AN INSTALLATION, REPAIR OR ADJUSTMENT. Care and thought must be given to locating the various pieces of equipment within a department. Keep in mind the importance of flexibility, and the handling of patients, so that procedures may be easily and quickly completed.

Do not leave a job unfinished. Remember, that an installation is not complete until the last bolt or nut is tightened; until a thorough inspection has been made and the apparatus is functioning satisfactorily, and until you have given full instructions on the operation of the equipment.

Clean up after you have finished. Do not leave pieces of wire, drops of solder, washers, rags or any dirt behind. Remember that in a hospital and around doctors--cleanliness is paramount--*a clean workman promotes his own good cause.*

No equipment, mechanical or electrical, can be expected to operate at maximum efficiency unless it is given proper attention. An automobile will continue to run for a long time even if the oil is not changed every two or three thousand miles. It will run along in a fairly acceptable manner even if it isn't greased for several thousands of miles. Spark plugs and distributor points do not necessarily require attention until the motor stops running.

Periodic inspection is to Medical Department Equipment what oiling, greasing, motor tune-up, etc. is to the automobile. It is calculated to keep the Medical Department Equipment in the finest possible operating condition at all times.

Obviously this regular inspection service cannot guarantee against all eventualities. Sometimes hidden, faulty conditions, may remain undetected even with these inspections. Unanticipated situations will arise which could not have been foreseen. Periodical inspection will prevent many difficulties, both minor and major, which might and probably would occur, without the benefit of this service.

In making these inspections examine all parts which do not require major dismantling, clean and oil all moving parts, check and adjust contacts if necessary, etc. Discuss any technical problems which may exist.

A good service man has the following qualifications:

Knowledge Of The Theory And Practice Of Electricity.
Knowledge Of Medical Department Equipments.
Ability To Cooperate With His Superiors And Other Members Of His Organization.
Good Workmanship.

You are going to work with many different types of equipment, and while the equipment in this school does not represent all the makes or types used by the Army, it is felt that after completing this course, the knowledge you have gained should qualify you to work on, and with, all of the various types of equipment in use.

The trade mark of a good workman is the condition of his tools and his ability to handle them skillfully. It is imperative that he keep his tools sharp, clean, oiled and in good condition.

Do not make the mistake of leaving tools behind.

In case of a breakdown of equipment the lack of tools may cause a complete shut down of a department and may even cause loss of life.

The Medical Department Tool Kit, supplied to graduates of this school, contains a complete set of high quality tools. These tools have been especially selected for the installation and maintenance of the various Medical Department equipments. They are expensive and in many cases replacement may be impossible. It is, therefore, necessary that they be kept in as perfect condition as possible.

Good workmen are judged by the manner in which they use tools. The use of a pair of gas pliers on a chrome-plated or painted surface immediately indicates that the workman is careless. If tools are tossed around in a haphazard manner, it not only indicates careless workmanship, but it also enhances the opportunity to leave tools behind. If a tool is broken, take immediate steps to have it repaired, re-sharpened, or replaced if possible before returning it to the kit. Failure to do this will result eventually in a set of tools that are extremely limited in their usefulness.

Use the proper size tool for each job. In the event an oversized screw driver is used, if one succeeds in getting the edge of the driver into the slot of the screw head, a large burr may occur as a result of a "slipping" out of the screw head slot. With the additional leverage obtainable with the oversized screw driver, it is possible to shear off the screw head. The same applies to using the improper size wrenches on machine bolts or cap screw heads. Always have a snug fit of the

wrench on the head of the bolt or nut and it will never slip. The use of an oversize wrench on a machine screw head may result in slippage. Thus the corners of the hexagon bolt may be knocked off, making it difficult to remove the bolt. Never use a pair of gas pliers on Hexagon or Square screws or bolts.

The following are common machine shop practices:

- Use proper size screw driver.
- Use proper size wrench.
- Never hit chilled steel with a hammer head.
- Keep files clean and do not file the top of a vise. (It is case hardened)
- Use handles on files.
- Do not use a screw driver as a cold chisel.
- Do not hammer on a finished surface, (use a block of wood as a buffer).
- Never cut piano wire with cutting pliers.
- Never use a drill that is bent.

A typical service problem may be the removal of a broken machine screw. Circumstances will indicate if the whole screw should be removed and replaced. There are various ways of making this type of repair.

The most common standard size screws used by most manufacturers are:

4-36 6-32 8-32 10-32 10-24 1/4-20 5/16-18

There are sizes larger and smaller than the above, but these represent the majority of the screw hardware encountered in medical apparatus. If circumstances permit, it is possible to replace an 8-32 screw, which has had the threads stripped, with a 10-32 screw. Drill the hole with a #21 drill and re-tap to a 10-32 thread. There may not be enough body of the material to tap out the next larger size hole; it may be necessary to drill completely through the casting and use a bolt and nut.

In the event a screw is broken off inside a trapped hole, it may be possible to drill out the portion of the screw in the hole and put in a larger size screw. To accomplish this, center punch the middle of the broken screw. Failure to center properly may cause the drill to run to the side and may cause it to break. If the screw is large enough (8-32 or larger), and there is not enough material to use the next larger size screw, remove the broken portion by drilling a small hole in the center of the broken off screw; then remove the shell.

Sometimes a tap will break. Removal of the tap can be accomplished by several means. "E-Z OUT" is a patented tool designed for removal of taps. This tool may be used to remove broken portions of machine screws and bolts. If such a tool is not available, the broken tap can be removed either by chipping the tap apart (easily done because the tap is made of chilled tool steel) or heating it to a red hot temperature to remove its temper and then it can be drilled out in the same manner as a screw.

Bear in mind that the various materials encountered in service work react differently to the various machining and tooling processes. For example, cast iron and steel are relatively simple materials to drill and tap. Provide lubrication on the tap (vaseline, lubricating or cutting oil) and back out the tap a half turn for every full turn you advance. This will keep the tap clean and reduce the possibility of breaking. Tapping a hole in brass is not too difficult but keep the shavings removed from the hole as much as possible. Remove the tap regularly. Threading a hole in aluminum requires considerable judgment as this material will have a tendency to tear rather than cut.

Bakelite and similar materials will tap comparatively easy, however care must be exercised that the tap does not run off center in these materials. When drilling and threading a hole, the drill and tap must be kept straight. Many drills and taps have been broken by lifting or lowering the drill or failing to start or maintain the tap in a straight line.

Some materials are extremely hard, for example, piano wire, blued steel, spring steels, and all case hardened surfaces. This type of material will turn the keenest edge of the finest tool. If a flat spring should snap off, remove the temper of the spring in the area of the repair only before drilling a new hole. Temper can be removed by heating with a flame. If necessary, piano wire can be cut with a cold chisel, however, it will nick the edge of the tool. The tops of all vises are case hardened. If a hack saw blade is run across the top of a vise the blade will lose a considerable amount of its cutting ability. Never hammer on a case hardened surface such as the top of a vise jaw with a steel hammer. Both the face of the hammer and the jaw of the vise are case hardened and they will chip.

SECTION XIII

HISTORICAL X-RAY

HISTORICAL X-RAY

X-Ray was discovered by Wilhelm Konrad Roentgen in 1895. Roentgen was a German scientist and Director at the University of Wurzburg. His experiments were performed in a small laboratory at this University and usually were repeated experiments of others. While working in a darkened room, and duplicating the experiment made by Hertz and Lenard with cathode rays in a Crookes tube, he noticed a glowing of barium-platino-cyanide crystals. After a systematic investigation, the rays responsible for this fluorescence became known as x-rays. Roentgen named the rays, "x-rays", because he did not know what they were, and since "x" represents the unknown in algebra, he used it to describe the rays. Roentgen's discovery included the efforts of many great scientists; Gilbert, Torricelli, Boyle, Ohm, Volta, Ampere, Faraday, Franklin, Henry, Crookes, Hertz, and countless others.

The medical profession was fast to make use of this new discovery for use in diagnosis, even though it took from 30 to 40 minutes to produce a radiograph of an ordinary hand.

Many men began to work to advance the science of x-ray. The Crookes tube was used as a basis. It was found that a concentration of gas in the tube produced more of these mysterious rays.

When the transformation of electrical currents through the Auto transformers and High Tension transformers was developed, the problem of generating x-rays became somewhat more simplified.

The strain on all equipment was greatly reduced with the introduction of the mechanical rectifier. This was a rotating switch which made current pass through the x-ray tube in one direction only. High voltage currents were carried on metal tubing near the ceiling known as "overhead" and insulated by use of mica, glass, or pressed paper supports.

Shortly before the first World War one of the greatest control factors for modern x-ray apparatus came into being. Dr. William Coolidge introduced the use of the hot cathode tube which incorporated a second circuit, separate from the high voltage circuit, known as the filament circuit. By means of the hot cathode tube and the filament circuit, it became possible to control the amount of current flow thru the x-ray tube with ease.

Dr. Potter and Dr. Bucky constructed the Potter-Bucky diaphragm. This device absorbs secondary radiations, which, if allowed to strike the film, would fog and otherwise interfere with good radiographic results. Today, this device is incorporated in all modern radiographic installations.

The mechanical rectifier or rotating switch has been replaced by valve tube rectification. The valve tube is an electron tube, resembling the x-ray tube in its principle of operation, but under normal circumstances the valve tube does not produce x-rays. These tubes are very efficient and eliminate the noise, radio interference and vibrations of mechanical rectifiers.

All of the above and many other improvements, led to the construction of equipment electrically safe. Apparatus designed to eliminate the possibility of shock is known as Shockproof equipment.

Modern, efficient design has permitted a marked reduction in the size of x-ray equipment; at the same time the various units are more efficient and powerful.

The increased capacities of the modern equipment has made it necessary to

develop accurate timers to control the length of exposure. Two types of timers are now in general use; the Synchronous timer, and the Impulse timer. Both are electrically operated, the latter being accurate to 1/60 of a second. Naturally, suitable relays, condensers, and numerous electrical devices are used in these highly technical mechanisms.

Rotating Anode tubes are now in general use with apparatus that possess capacities up to 500 Milliamperes. This tube greatly increases the allowable tube currents and also improves the quality of radiographs.

Like rectifiers, timers and tubes; the accessories of tables, tube stands, cassette changers, stereoscopes. cassettes, and illuminators, have constantly improved in design and efficiency.

The use of x-ray has extended itself to a very diversified field. In the medical field, x-rays are used for Radiography, Fluoroscopy, and Therapy. Both the Medical and Veterinarian professions utilize x-ray for therapeutic purposes.

Machines operating up to 1,000,000 volts are used for both therapeutic and industrial purposes. All important castings, weldings, and materials up to, and equivalent of, eight inches of steel may be radiographed with modern equipment. Industry also uses x-ray for crystal analysis, to study fine structures of materials by diffraction.

Fruit growers are making use of fluoroscopy to determine solid fruit for packing. Defective fruits show plainly when examined fluoroscopically.

Candy bars, peanuts, cigarettes, tobaccos, canned foods and numerous items of merchandise are routinely inspected by means of a fluoroscope to detect foreign objects.

Federal authorities utilize x-rays to complete inspection of floors, walls, furniture and locked baggage. Clothing can be inspected without the suspect being aware of the action.

In the short span of forty-eight years, the science of x-ray has contributed much to the welfare of civilization.

SECTION XIV

THE EFFECTS OF X-RAY RADIATION

THE EFFECTS OF X-RAY RADIATION

The question "Just how does exposure to x-ray effect the human body?" is not new. The following - brief - abstracts have been made from chapter XX, page 247 and chapter XXI, pages 257-258 and 260 of "X-Ray and Radium in the Treatment of Diseases of the Skin" by George M. MacKee, M. D.

"It has long been known that x-rays are capable of reducing the leukocyte (a white blood corpuscle) count in leukemic (pertaining to leukemia) as well as in normal blood."

"Physicians and others who employ x-rays or radium for medical purposes and who, therefore, may be exposed to these agents at frequent intervals may, and not infrequently do, suffer ill effects. One of the earliest evidences of injury from this cause is leukopenia (Diminution in the number of white blood corpuscles). Because of the shorter distance at which it is commonly employed, and often because of careless handling, radium is more dangerous than x-rays. However, leukopenia in a person whose work includes the use of x-rays or radium does not necessarily mean overexposure to them, as is so often erroneously assumed. The leukopenia may be due to other factors, such as chronic infection, and may have nothing to do with radiant energy. If the leukopenia is slowly progressive, if no other possible or adequate cause can be discovered, and if the circumstances under which the affected individual has been working clearly point to overexposure from inadequate protection, the relationship between the leukopenia and x-rays or radium may be inescapable. When the irradiated area includes lymphoid tissue the numerical drop in white cells is more pronounced and of longer duration. The lymphocytes (lymph corpuscles or cells) diminish from the time of irradiation. The leukopenia reaches its maximum in from two to ten days after which there is a slow return to the normal, three or more weeks being required for complete recovery assuming that the injury is not beyond repair. Small doses either have no effect on the normal blood picture or there may be a temporary leukocytosis, (a transient increase in the number of white corpuscles in the blood) mainly a lymphocytosis (an excess of lymphocytes in the blood). The result naturally depends upon the dose, the intervals between exposures, and all parts irradiated. After intensive irradiation hyperplastic (overgrowth of a part due to multiplication of its elements) changes in the bone-marrow have been observed, while the spleen and lymph nodes show atrophy and reduction in size. The polymorphonuclear leukocytes are somewhat less sensitive than the lymphocytes. After irradiation, the former cells often exhibit a peculiarity of reaction practically never seen with lymphocytes. For a short time after exposure to x-rays or radium the number of polymorphonuclear cells in the blood may increase rapidly, but this increase seldom lasts more than twelve or eighteen hours; after this their number steadily diminishes and falls below the normal level, where it may remain from a few days to three or more weeks according to the dose of rays. Gradual regeneration then takes place. When irradiation has been repeated many times, however, regeneration of the polymorphonuclear cells may be slow and may never be complete.

Exposure to x-rays or radium of the thorax or of the abdomen has a greater influence on the leukocytes than exposure of other parts of the body. In this respect irradiation of the upper half of the abdomen is most prone to affect these cells; this is probably related to the great mass of blood in the liver, spleen, kidneys and intestine."

This material is presented to reaffirm the warning that Excessive Exposure to X-Radiation must be avoided. For a more thorough study of this effect, the publication mentioned above is recommended as one of the latest publications covering this subject.

LEA & FEBIGER - 1938

Leukocyte -
A white blood corpuscle.

Leukemic -
Pertaining to leukemia

Leukemia -
A fatal blood disease with a great increase in the number of white blood corpuscles.

Leukopenia -
Diminution in the number of white blood corpuscles.

Lymphocytes -
Lymph corpuscles or cells.

Leukocytosis -
A transient increase in the number of white corpuscles in the blood.

Lymphocytosis -
An excess of lymphocytes in the blood.

Hyperplastic -
Overgrowth of a part due to multiplication of its elements.

SECTION XV

X-RAY PROTECTION

WARNING

X-Ray Equipment is Dangerous to Both Patient and Operator Unless Established Safe Exposure Factors are Strictly Observed

Though x-ray apparatus is built to the highest standards of electrical and mechanical safety, the useful x-ray beam becomes a source of danger in the hands of the unauthorized and incompetent operator.

Adequate precaution should be taken to make it impossible for unauthorized and unqualified persons to operate this equipment or to expose themselves or others to its radiation.

Before operation, those qualified and authorized to operate it should become familiar with the established safe exposure factors by a careful study of the National Bureau of Standards "Handbook HB20," "The United States Army X-Ray Manual," "The Recommendations of the International Roentgen Ray Committee on X-Ray Protection," and other standard authorities.

FLUOROSCOPY - The following fluoroscopic precautions and procedures shall be observed.

The operator shall allow his eyes to become fully accommodated to the darkness before starting any fluoroscopic examination. This may be done by remaining in a dark room or wearing fluoroscopic goggles provided with special dark lenses. AT LEAST FIVE TO TEN MINUTES ARE NECESSARY FOR PROPER ACCOMMODATION OF THE EYES BEFORE THE FLUORSCOPIC WORK IS STARTED.

Failure to observe this rule will result in unsatisfactory fluoroscopic vision and will tempt the operator to increase the milliamperage, kilovoltage, and time beyond the recommended minimum value and thus expose the patient, and under certain conditions himself, to dangerous amounts of radiation. This rule applies with particular emphasis to the use of head type fluoroscopes.

The x-ray protective devices, such as lead rubber gloves, lead rubber aprons, lead protective fluoroscopic chairs, etc., shall always be used. No part of the operator's body shall be exposed to the x-ray beam.

Short intermittent exposures should be used, rather than long continued ones. This practice allows the eyes to re-accommodate during the dark intervals and increases the visibility of the image. It also reduces the amount of radiation the patient receives and prolongs the life of the x-ray tube. To prevent needless exposure to other parts of the patient's body and to improve the sharpness of the fluoroscopic image, the smallest area necessary to cover the part being examined should be used, by limiting the fluoroscopic area with the diaphragm or shutters.

THE BEST PRACTICE IS TO USE A MINIMUM OF ONE MM. ALUMINUM FILTER OR ITS EQUIVALENT BETWEEN THE X-RAY TUBE AND THE PATIENT.

The milliamperage shall be as low as possible without sacrificing satisfactory fluoroscopic vision. The milliamperage shall in no case exceed 5 M.A. The kilovoltage shall be set in accordance with the thickness and the density of the part being examined. For best vision it should be kept as low as possible, and although the rating of the machine may be 100 P.Kv. or more, do not use more than 85 P.Kv. except in rare cases. It is common practice to use no more than 3 M.A. at 85 P.Kv. for abdominal fluoroscopy, 3 M.A. at 70 P.Kv. for chest, and 3 M.A. at 60 P.Kv. for extremities.

The distance between the target of the x-ray tube and the patient's skin shall be at least ten inches. Greater distances are preferable since they reduce the likelihood of over-exposure and also improve the fluoroscopic image. The intensity of the x-ray radiation reaching the patient's skin varies inversely as the square of the distance from the target of the x-ray tube. For example, the intensity of the x-ray radiation at ten-inch distance is four times that at twenty-inch distance, all other factors remaining the same.

Consult the tube rating charts for maximum permissible time, kilovoltage, and milliamperage ratings which apply to the fluoroscopic tube. Never exceed these ratings. A fluoroscopic timer is an excellent safety device. It helps to keep within the safe exposure time limits. When the same tube is used for both fluoroscopy and radiography, it must be remembered that the maximum radiographic ratings do not apply to a tube which has already been heated by considerable fluoroscopy.

Keep a record of exposure factors used during the examination. Since the effect of x-radiation is cumulative, be certain that the amount the patient is

subjected to, together with the amount, diagnostic or therapeutic, which the patient may have received during the period of four weeks preceding, together with the amount which will be used for radiography during the course of the examination, does not in its combined total for any area, exceed the generally accepted maximum safe limits.

As a guide in determining the safe exposure factors, consult the following tables of maximum permissible exposure values in milliampere-seconds. Milliampere-seconds are the product of milliamperes and total actual exposure time in seconds. In using these tables, the maximum permissible exposure time in seconds is obtained by dividing the milliamperes used into the value of milliampere-seconds tabulated, as for example, if the milliamperes used are 5, and the permissible exposure value in milliampere-seconds totals 1,000 at a given filtration and distance, the milliamperage (5) is divided into the milliampere-seconds (1,000) and which gives the time-200 seconds; this figure constitutes the maximum exposure time.

I

Maximum Permissible Exposure Values in Milliampere-Seconds For All Parts of the Body Excepting the Head

Target-Skin Distance Inches	Filter—mm Al. External—None Inherent—0.5 Total—0.5	Filter—mm Al. External—0.5 Inherent—0.5 Total—1.0	Filter—mm Al. External—1.0 Inherent—0.5 Total—1.5
10	265	510	810
12	380	730	1090
14	520	1000	1500
16	680	1300	1950
18	870	1650	2500
20	1060	2050	3000
22	1280	2450	3640
24	1530	2900	4360

II

Maximum Permissible Exposure Values in Milliampere-Seconds For the Head

Target-Skin Distance Inches	Filter—mm Al. External—None Inherent—0.5 Total—0.5	Filter—mm Al. External—0.5 Inherent—0.5 Total—1.0	Filter—mm Al. External—1.0 Inherent—0.5 Total—1.5
10	200	380	610
12	290	550	875
14	390	750	1190
16	510	970	1560
18	650	1240	1980
20	800	1530	2450
22	960	1840	2970
24	1150	2150	3540

NOTES ON THESE TABLES

These tables apply to both fluoroscopy and radiography.

The first table applies to all parts of the body excepting the head; the second to the head only. The second table is a reduction of approximately 25% of the values of the first.

These tables are based on operation at 85 kv. When using higher kilovoltage, a reduced value must be used. When using a lower kilovoltage, an increased value may be used, but it is preferable to employ the tabulated values and take advantage of an increased margin of safety.

For adjustment of these tables when using a kilovoltage different than 85 Kv, the following percentage changes may be used:

Kv	Change in Maximum Permissible Exposure Values
100	Reduce by 25%
90	Reduce by 8%
85	No change
80	Increase by 10%
70	Increase by 35%
60	Increase by 80%

For the user's information, the total filtration value heading each column is divided into inherent and external. The values of permissible milliampere seconds still apply when this same total is obtained by a different division of the inherent and the external filter. The inherent is dependent upon the particular filtering characteristics of the tube aperture and table top being used (for fluoroscopy).

The values of these tables are based on:

The average output of a typical installation;
The average figure of 275 roentgens for a "threshold erythema";
A factor of 50% which is necessary to cover unpredictable variations in either of the first two factors.

These values are intended to serve only as a guide and should be replaced by similar styled tables based on the actual measured output of the installation and the user's estimate of the value of the threshold erythema.

For assured safety, these tabulated values shall not be exceeded until replaced by the user's own values.

THERAPY

(Superficial, Light, Intermediate, or Deep X-Ray Therapy)

X-ray equipment should not be used for x-ray therapy unless a therapeutic calibration or standardization is made by a radiation physicist.

Any subsequent change in location, x-ray tube, equipment, filters, or power supply may alter the radiation output, making additional calibration necessary.

In using x-ray equipment for therapeutic purposes, it may be necessary to administer dosages which approximate those dangerous to normal tissue. Adequate but safe dosage is dependent upon the diagnosis of each individual case, the location of the pathological condition and the peculiarities of the patient. Therefore, the re-

sponsibility for prescribing dosage and its method and schedule of application must rest solely with the physician and it is impossible for the manufacturer to indicate dosages, methods or schedules of application.

Warning, however, is given that the use of x-ray therapy should, under no conditions, be attempted by a physician without previous thorough training in the principles of radiation therapeutics.

Because of the hazards of the cumulative effects of radiation in x-ray therapy, as well as for other reasons, complete records should be maintained in each case. These should include all past history which may have an influence on the diagnosis or treatment of the pathological condition and should particularly include all details of any previous exposure to x-radiation. These records should be kept in accordance with recommendations of the scientific societies or recognized text books on this subject and should accurately record the radiation intensity in roentgens per minute, dosage, location and size of treatment area, treatment distance, kilovoltage, milliamperage, filter used, time, etc.

Various types of treatment timers, constancy meters and integrating dosimeters are available for use as means of providing convenient measurements of desired dosage.

There are cones of various sizes and lengths available to limit the size of the treatment area and more easily gauge the treatment distance.

X-RAY PROTECTION - Harmful effects to the health may be experienced by anyone exposed to an excessive amount of x-radiation. This must be avoided by adequate protection.

The most important consideration should be given to the protection against the direct beam. However, when x-rays strike any material there is produced a secondary or scattered radiation and, as this is as potentially dangerous as the direct radiation, protective measures must be employed to guard against it also.

The adequacy of the protection may be checked by a fluoroscopic screen or films placed in important locations or carried on the person. Adequate protection may also be confirmed by actually measuring the radiation at any point to see that it does not exceed the accepted tolerance dose. Another worthwhile procedure is the frequent blood testing of the personnel occupied in radiological work.

The Advisory Committee on X-Ray Protection has published in the Bureau of Standards' "Handbook HB-20" their detailed recommendations for this protection. A few pertinent paragraphs are quoted below; the reader is directed to this Handbook for COMPLETE Protective information. These recommendations must be followed to avoid danger.

GENERAL RECOMMENDATIONS - 1.10 "All x-ray rooms (except for dental radiography) or booths shall be lined throughout with sheet lead or equivalent material of assured quality, uniformity and permanency, care being taken that there be complete overlapping of all joints. 'Protective plasters' and lead rubber wall board are considered to be unsatisfactory for providing protection exceeding 1 mm lead equivalent."

1.14 "The following lead equivalents are recommended as adequate:

TABLE 2

X-Rays Generated by Peak Voltages Not in Excess of	Minimum Equivalent Thickness of Lead
Kv	mm
75	1.0
100	1.5
125	2.0
150	2.5
175	3.0
200	4.0
225	5.0

REQUIREMENTS FOR DIAGNOSTIC PURPOSES UP TO 130 Kv

2.03 "The equivalent of 1 mm of aluminum shall be permanently mounted between the tube target and patient in all fluoroscopic tube inclosures and 0.5 mm of aluminum in all radiographic tube inclosures. Part or all of this may be contained in the glass of the tube walls."

2.12 "Radiographic and radioscopic rooms shall be lined throughout with at least 0.5 mm of sheet lead or equivalent material of assured quality, uniformity and permanency. (Exception--This may be omitted only on outside walls and sides adjacent to unoccupied rooms)."

2.13 "To protect the operator and personnel, control apparatus for radiographic work should be in an adjacent room which provides protection equivalent to at least 0.5 mm of lead. Control operators should be behind such protection during all radiographic exposures, and during all radioscopic work when practicable."

2.14 "When it is impracticable to place the control apparatus in an adjacent room, as in paragraph 2.13, it may be inclosed in a lead-lined booth within the radiographic room."

2.15 "Either control room or booth shall be provided with a suitably large lead-glass window of 2.0 mm lead equivalent."

REQUIREMENTS FOR THERAPY APPARATUS UP TO 140 Kv

3.04 "When the x-ray tube is so arranged that the radiation can be taken off in only one fixed direction, a sheet of lead 2.5 mm thick shall be placed in the path of the direct and useful beams on the floor, wall or ceiling opposite the diaphragm. This lead sheet shall extend one foot in all directions beyond the edge of the x-ray beam, determined by the largest possible aperture in the tube inclosure."

3.05 "When the x-ray tube is so arranged that radiation can be taken off in several directions, all parts of the room which may possibly be reached by the direct or useful beam of radiation shall be lined with sheet lead 2.5 mm thick. The lead lining of this thickness shall extend one foot beyond the edge of the beam for any position of the tube inclosure with its largest possible diaphragm aperture. When there is any doubt as to the limits of the beam the whole room should be lined with 2.5 mm of lead."

3.06 "Protection from direct and useful radiation as indicated in Paragraph 3.04 and 3.05 may be omitted only on sides adjacent to permanently unoccupied rooms or

outside building walls."

3.07 "In case of Paragraphs 3.04 and 3.05, the entire remaining portions of the room shall be lined with sheet lead 1.5 mm thick."

3.08 "All control apparatus shall be located in an adjacent room or in a completely inclosed well-ventilated booth lined with 2.5 mm lead. Such a room or booth shall be provided with a suitably large protective glass window or windows of 2.5 mm lead equivalent, so placed as to afford ready view of the patient and meters while the operator is in a normal and comfortable position."

3.09 "The tube container and treatment table should be so arranged that the useful beam points away from the technician's booth, offices, etc."

REQUIREMENTS FOR THERAPY APPARATUS UP TO 220 Kv

4.05 "When the x-ray tube is so arranged that the radiation can be taken off in only one fixed direction, a sheet of lead of thickness in accordance with Table 2 shall be placed in the path of the direct or useful beam on the floor, wall or ceiling opposite the diaphragm. This lead sheet shall extend one foot in all directions beyond the border of the x-ray beam determined by the largest possible aperture in the tube inclosure."

4.06 "When the x-ray tube is so arranged that radiation can be taken off in several directions, all parts of the room which may possibly be reached by the direct or useful beam of radiation shall be lined with sheet lead in accordance with Table 2. The lead lining of this thickness shall extend one foot beyond the edge of the beam for any position of the tube inclosure with its largest possible diaphragm aperture. When there is any doubt as to the limits of the beam, the whole room should be lined with lead in accordance with Table 2."

4.07 "In the case of Paragraphs 4.05 and 4.06, the entire remaining portions of the room shall be lined with sheet lead having a thickness of at least equal to one-half the values specified in Table 2."

4.08 "All control apparatus shall be located in a separate room."

4.09 "Such control rooms shall have a protective glass window or windows of the same lead equivalent as the wall and should be so located that the operator may, while in a normal and comfortable position have a ready view of the patient and meters."

SECTION XVI

ELECTRICAL HAZARDS IN X-RAY WORK

ELECTRICAL HAZARDS IN X-RAY WORK

Manufacturers have done much to minimize the possibility of electric shock from an x-ray unit. Low-voltage wires are well-insulated and concealed. The high-voltage wires from the transformer to the x-ray tube are insulated in shockproof cables. However, as a repair man, you will be exposed to, and must develop a great respect for electrical hazards.

Everyone of you, at one time or another, has received an electric shock. Few of you have had any experience with voltages above 460. The possibilities of a "shocking" experience in your new field of work is proportional to the care exercised.

The common term "low-voltage" is meant to describe voltage up to, but not over, approximately 460 volts. Voltage above this value (460) is commonly referred to as "high-voltage" or "high-tension". In x-ray work, the voltages range from 30,000 to and above 2,500,000 volts.

The use of shockproof equipment is now so prevalent that high-tension hazards have been practically eliminated. However, the safety provided by this type equipment is itself a danger because it is likely to relieve the mind of the serviceman or the operator of this electrical hazard. After handling shockproof equipment, there is considerable likelihood that some individuals may fail to recognize the electrical hazards which exist as far as the operation of non-shockproof equipment is concerned. Moreover, everyone should realize that regardless of self-contained tube heads (i.e. when the x-ray tube is immersed in oil and contained in the same tank which accommodates the high tension transformer), or with the use of shockproof cables, one is still handling currents of exceptionally high-voltage which under certain conditions might resist the protective provisions. Therefore, even with modern shockproof equipment, the possibilities of electrical hazards should be respected.

Never attempt to determine if a line is alive by touching the wire. Should you find it necessary to do any repair work, before you start to work about the x-ray machine, *BE CERTAIN THAT THE MAIN SWITCH IS OFF.*

Never close any switch on an x-ray machine unless you are certain that no one will be injured. Never lose sight of the fact too, that excessive exposure to x-ray radiation is also dangerous. Therefore, before pressing the exposure switch on any unit, make certain that the x-ray beam is directed away from the body.

Learn to distinguish shockproof and non-shockproof x-ray tubes. In the majority of x-ray tilt tables, the x-ray tube used for fluoroscopy is generally of non-shockproof design. Therefore, if any of the protective shields are not replaced on an x-ray table following a service repair, contact with high-tension is possible.

Should you encounter high-voltage (200 K.V.P. up) therapy generator utilizing condensers, never work on such a unit until the condensers have been discharged and grounded.

The hazards of contact with high-voltage circuits are generally appreciated, and precautions, which must be exercised in the vicinity of this equipment, are generally well-understood; death, however, may result from any one of four physiological effects:

1. The ventricles of the heart may be thrown into fibrillation from which, in the human, they seldom if ever recover.
2. Tetanic convulsion of the respiratory apparatus may result, with resultant

fixation of the muscles of the thorax and the diaphragm into the phase of deep inspiration.

3. The brain centers concerned with constriction of blood vessels may be so stimulated as suddenly to produce extreme blood pressure with resultant hemorrhages.
4. The resistance on the part of the tissues to the flow of the electrical current may be so great as to produce extreme accumulations of heat with the result of actual charring.

Contrary to general belief, voltage is not the factor directly responsible for any of these effects. It is amperage that causes fatalities, and of greatest importance is the volume of current which is effective upon the heart. It has been estimated that for the frequencies of current utilized with most radiographic equipment (60-cycle), the human heart will tolerate no more than 6 to 15 milliamperes. The heart is involved to the greatest extent when the electrical contact includes one upper extremity and the opposite lower extremity, for with such a contact, approximately 10 percent of the total current involves the heart. Interpreted as total current flowing through the body, by such a route, a minimal lethal value would amount to between 60 to 150 milliamperes. Some individuals have idiosyncrasies (either because of defects in their heart or because of an overly excitable nervous mechanism), and they cannot tolerate even the lower of these values. It is estimated that approximately 90 percent of maleffects incident to electrical shock are those concerned with the heart - hence the importance of these considerations. With high-voltage and low-amperage (i.e. milliamperage), there is a tendency for an individual to be thrown for a distance. With lesser voltages and sufficient current to stimulate muscle contraction, a complete gripping contact is likely. A certain amount of voltage is required to overcome the resistance of the skin and superficial tissues. This value varies, depending upon the dryness of the skin, the thickness of it, and the amount of fat contained in the subcutaneous tissues. With very moist skin and a thin individual, it has been estimated that only 65 volts will overcome the body resistance.

Regardless of the unfavorable possibilities, every effort should be made to restore a victim from electrical shock. However, in rescuing a person in contact with an electric circuit, one should never directly grasp the individual because by so doing the result will most likely be suicide with the accomplishment of no aid whatsoever to the first victim. Instead of plunging to one's death, the first objective should be to break the electrical circuit by opening a switch. Perhaps the victim might be disentangled by throwing over him a sheet or rope or some other nonconductor and then forcibly removing him from his contacts. Thereafter he should be treated as a victim of shock. He should be placed in the lying position, prone with his face turned to one side and chin resting on the back of one of his hands - to provide for freedom of breathing. His collar and other clothing should be loosened and then the Schaeffer method of resuscitation (as used for the semi-drowned) should be instituted. The chest manipulations should be continued at a rate of about 12 to 15 times per minute, without despair, for as long as 2 to 4 hours - awaiting the arrival of a doctor.

This treatment is effective in only a small percentage of cases. However, one should not despair in attempting to revive a victim of this sort. THE POOR RESULTS OF TREATMENT SHOULD EMPHASIZE THE IMPORTANCE OF AVOIDING THE POSSIBILITIES OF ELECTRICAL SHOCK. Conspicuous warnings should be posted wherever dangers exist. With roentgenographic equipment, exposed condensers are examples of such dangers. It should be realized that these condensers may discharge even though the machine is not in operation. They may discharge hours and even days later.

The danger of operating roentgen-ray equipment near combustible anesthetics has long been recognized. Many examples of such accidents are recorded. The anesthetics involved were ether, ethyl chloride, cyclopropane and ether-nitrous oxide-oxygen.

Very few, if any, of the modern x-ray equipments are sparkproof. Complete sparkproof equipment is less practical than the use of non-combustible anesthetics. To quote the National Board of Fire Underwriters:

> "In the operating room and elsewhere the use of x-ray machines in the presence of any combustible anesthetic should be prohibited."

The first three letters of the alphabet will serve to summarize the warnings in the foregoing, ABC - Always Be Careful.

SECTION XVII

PRINCIPLES OF X-RAY PHYSICS

TRANSFORMERS - The operation of a transformer is based on two fundamental principles in electricity: A coil of wire carrying an electric current will have produced in its vicinity a magnetic field, the intensity of which is a function of the strength of the current and the number of turns of wire in the coil.

A coil of wire situated in a magnetic field of changing intensity will have induced in it an electric potential which is proportional to the rate of change of the magnetic field and the number of turns in the coil.

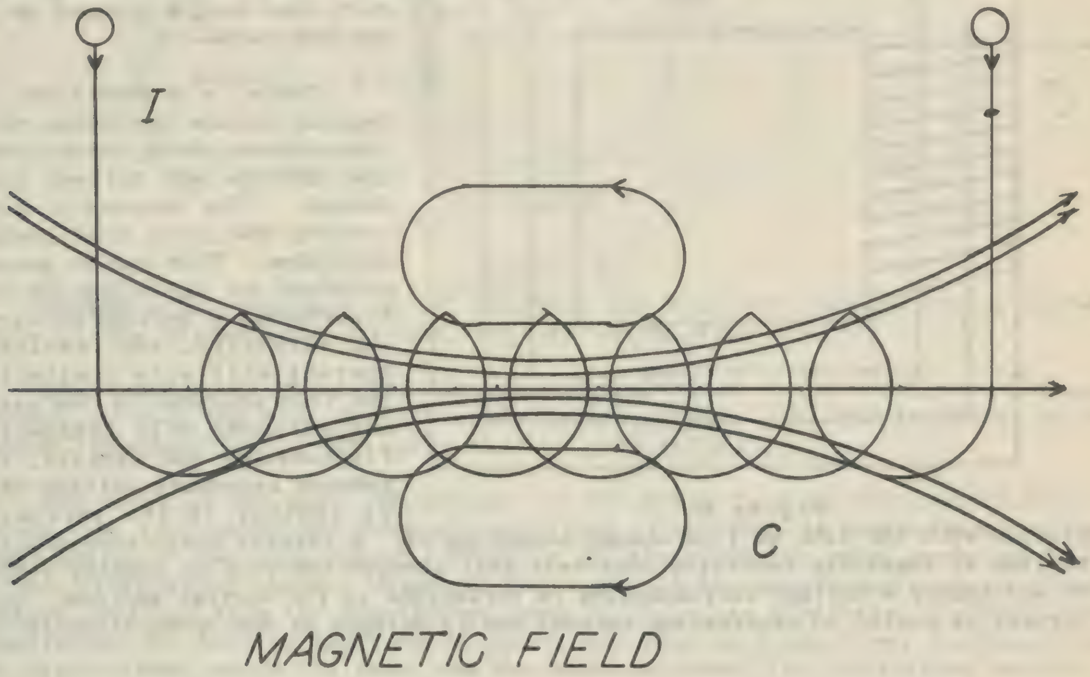


Figure A

Figure A illustrates the magnetic field formed in the vicinity of the coil (C) carrying a current (I). The lines form closed loops, the arrows indicating the north pole of the magnetic field. In order to increase the intensity of magnetization, the air medium through which the lines pass may be replaced by iron and to further increase the efficiency, the path of the magnetic flux is closed, as shown in Figure B. All of the magnetic effect of the electric current (I) in the coil (C) is then confined to a closed path of good magnetic conductivity, the direction of the flux lines being as indicated.

In Figure C a second coil has been wound on the same core, both being electrically insulated from the core and from each other. Coil (N_1) carries a current produced in it by the external electromotive force (E_1). A magnetic field or flux is established through the core around which coil (N_2) is wound, producing in this coil a potential (E_2) which is dependent upon the rate at which the flux changes and the number of turns (N_2). Since the changing magnetic flux is common to both coils, the voltage per turn induced in each must be the same. The voltage induced in (N_2) will be approximately equal to the applied electromotive force (E_1). Then

$$\frac{E_1}{N_1} = \frac{E_2}{N_2}$$

where E_1 = primary voltage, E_2 = secondary voltage

N_1 = primary turns, N_2 = secondary turns

Electrical power at any given voltage can be converted to power at any desired voltage by proper selection of the turn ratio. For energizing the filament of the x-ray tube, the supply voltage of 230 volts can be reduced to 10 volts by means of a step down transformer. To obtain the high tension necessary for electron acceleration, the 230 volt line may be stepped up to 100,000 volts.

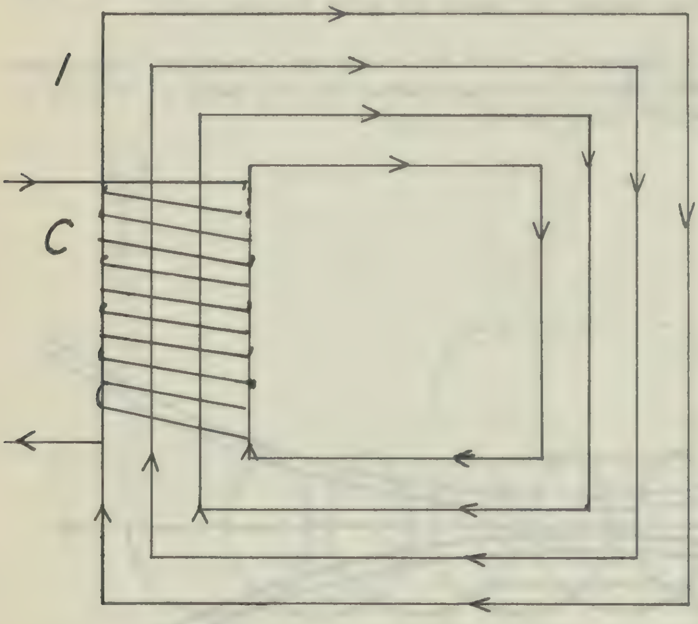


Figure B

There is a condition essential to the operation of a transformer which establishes the voltage and current produced. The magnetic flux linking the coils must change with time. This can be accomplished by applying to the transformer a voltage of varying intensity, the resultant current will vary similarly, the flux produced by the varying currents will follow its fluctuations and finally, the induced secondary voltage will be similar in its intensity variation with the rate of flux change producing it. A current which reverses its direction at regularly recurring intervals will reverse the flux at similar intervals and induce a voltage corresponding in variations to the voltage applied. Such a current is called an alternating current and is defined as one whose direction of

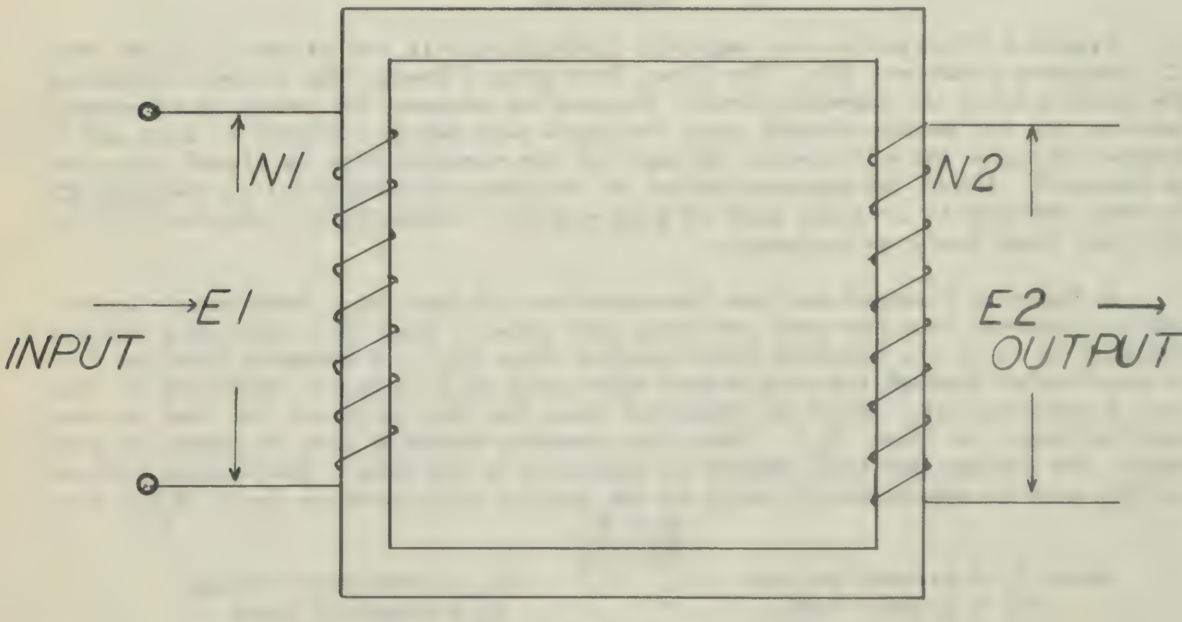


Figure C

flow reverses at regularly recurring intervals, most generally with successive half waves of the same shape when instantaneous values are plotted against time, as shown in Figure D.

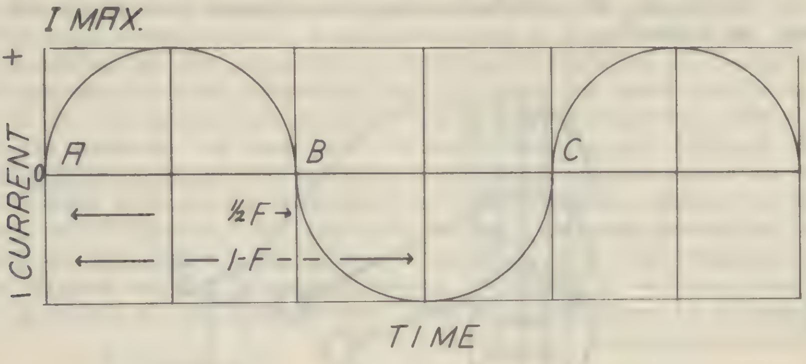


Figure D

CYCLES - One complete set of positive and negative voltage values is one cycle of the alternating current, (A) - (C) in the Figure D.

The frequency is the number of cycles through which the current passes in one second, so that the time for one cycle is 1-F seconds. If the frequency is 60 cycles, the duration of one cycle will be 1/60 second.

The shape of the wave illustrated is the basic form in alternating current theory, the sine wave, for which the amplitude at any time is proportional to the sine function of the angle passed through by the electromotive force producing coil in the alternating current dynamo. This wave is the approximate shape of the voltage obtained from the transformer used in the x-ray generator; the step-down transformer for heating the tube filament, the step-up transformer for supplying the high voltage across the tube, and the autotransformer for controlling the input voltage to the high-tension transformer.

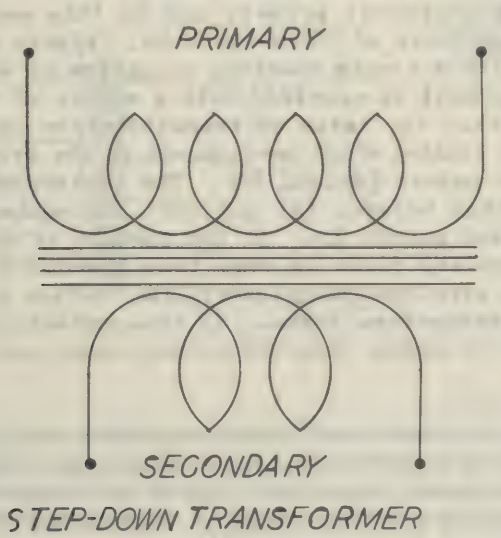


Figure E_1

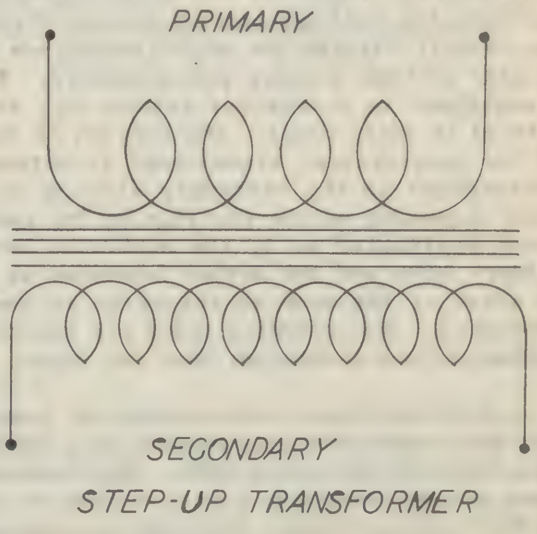


Figure E_2

STEP UP AND STEP DOWN TRANSFORMERS - It is convenient to represent the transformer in circuit diagrams as shown in Figures E_1 and E_2. Figure E_1 is a step-down transformer as used for filament heating, with a turn ratio of approximately 20 to 1. Figure E_2 is a high-tension transformer for which the turn ratio may be 1 to 500, or higher.

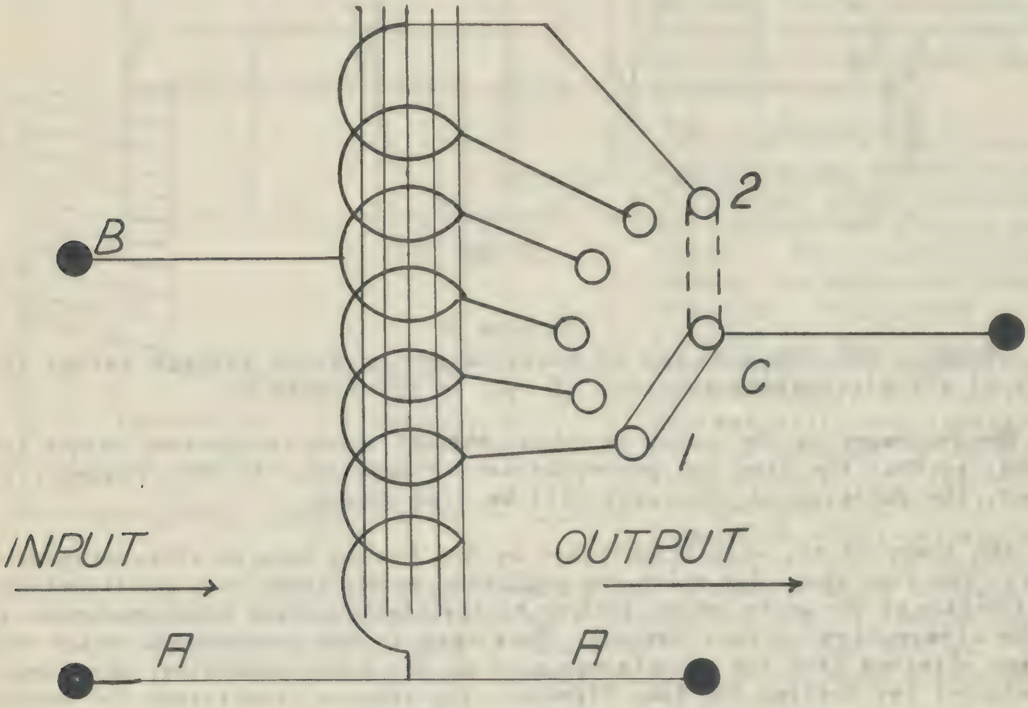


Figure F

AUTOTRANSFORMER - The autotransformer is a device which supplies a variable voltage input to the high-tension transformer primary and in this manner controls the voltage applied across the terminals of the x-ray tube. Figure F is the circuit diagram for such transformer with a single winding, a portion of which is used as both primary and secondary. The coil is provided with a number of taps brought out to a selector switch (C), so that the ratio of transformation can be altered in small steps. The portion of the winding which corresponds to the primary of the conventional transformer is between points (A) and (B). The portion which corresponds to the secondary winding is that between (A) and (C), the number of turns depending on the position of the control switch (C). If the contact is on the point designated as 1, the number of secondary turns is less than the number of primary turns and the device functions as a step-down transformer, the voltage ratio of which is the same as the ratio of the respective turns. If the contact is in position 2, the secondary turns are greater in number than the primary turns and the voltage output is greater than the input.

By providing a large number of taps, voltage transformations above and below the input value may be obtained in a sufficient number of steps to provide 1 kv.p. variations to the x-ray tube. The autotransformer has a small ratio of transformation, rarely exceeding 2 to 1 so that it can be safely mounted in the control stand of the x-ray generator with the selector switch easily accessible.

BASIC X-RAY CIRCUIT - We have now developed the theory of the alternating

current transformer to the point where it can be utilized as a source of electrical energy for the operation of the x-ray tube; a step-down transformer supplying approximately 10 volts for heating the filament, a step-up transformer with an output of up to 140 kv.p., and an autotransformer to provide the variation in input voltage to the high-tension transformer. These are shown in Figure G. The filament supply voltage is controlled by the rheostat or variable resistance in the primary circuit. The filament ammeter is also placed in this circuit for ease in shockproofing. It can be mounted in the control stand where it is easily visible. The calibration of the meter scale, however, is such that it reads the current through the x-ray tube filament. The high-tension transformer secondary is connected to the anode and cathode of the tube with the milliammeter at its midpoint, again for ease in shockproofing since the center of the transformer is at ground potential and the meter can be mounted on the control apparatus. The primary of the step-up transformer is fed from the output of the autotransformer so that its voltage can be varied in small steps by means of the switch (C). The circuit shown is a simplification of

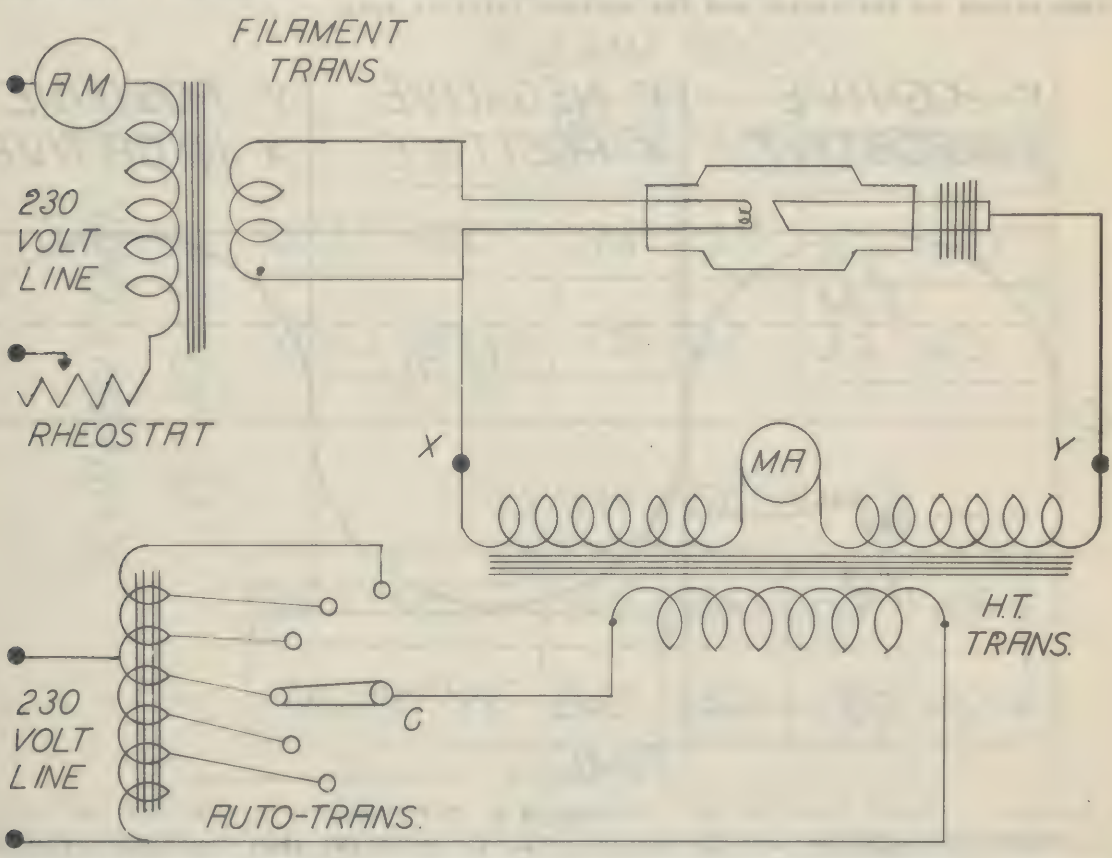


Figure G

that generally employed, many refinements being omitted in the interest of clarity. Such a scheme, in its expanded form is quite generally used and is known as the self-rectified circuit. From what has already been said of alternating currents and transformers, it is readily recognized that the voltage output of the step-up transformer is an alternating one of approximately a sine wave shape, similar to the alternating current supply from the power line. The potential of (X) and (Y), then, is periodically changing from positive to negative, the reversal taking place 120

times each second with a supply frequency of 60 cycles. The potential of the anode, being the same as that of (Y), is alternately positive and negative while the cathode is alternately negative and positive. From foregoing electron theory, we know that the negatively-charged electrons are accelerated in the direction of the anode only when the latter is positively charged, and the x-rays are generated only when electron acceleration takes place. As a result, current passes through the tube for only one half of each cycle, being suppressed for the following half cycle. This is shown in Figure H, the variation with time of the x-ray tube current.

In this figure the shape of the current wave is a departure from the approximate sine wave because the voltage-current characteristics of the x-ray tube are not linear, but this need not be confusing. It is important to note that current passes through the tube in alternate half cycles when the transformer polarity is such that (Y), the anode potential, is positive and (X), the cathode potential, is negative. During the intermediate period, when the anode voltage is negative, no electrons are drawn across to the target and the current falls to zero.

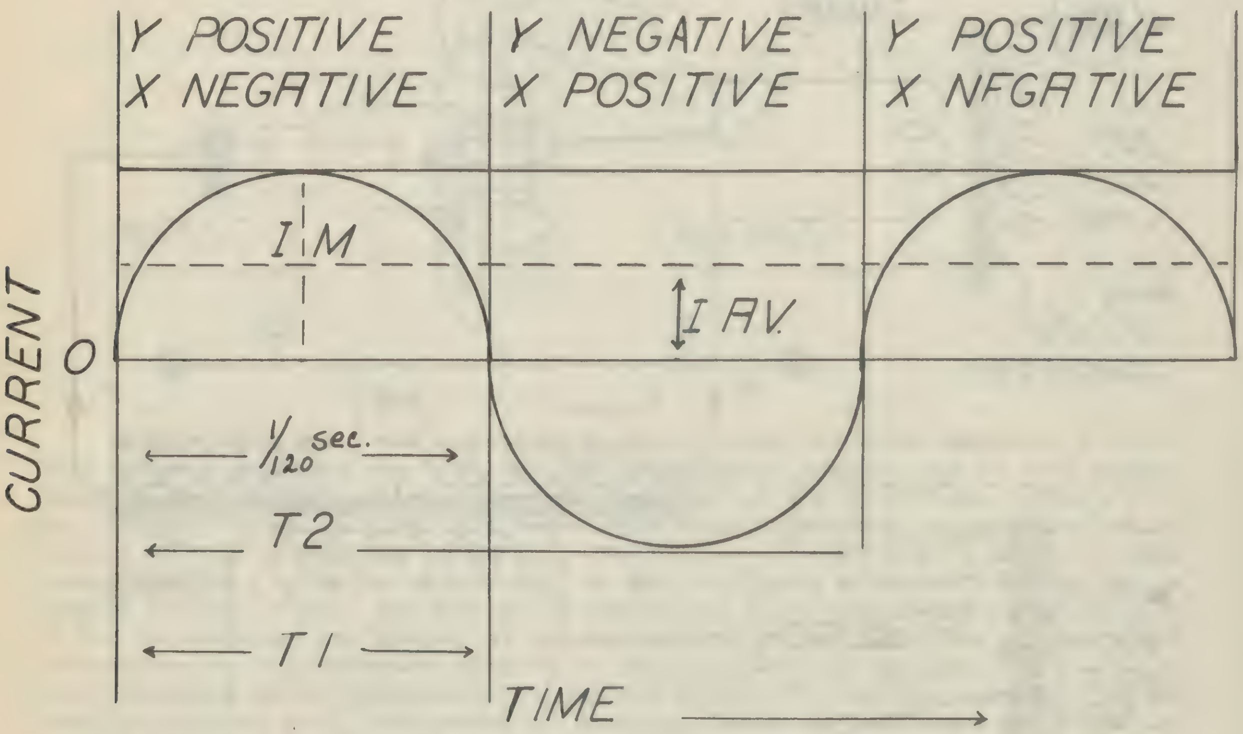


Figure H

With (Y) negative and (X) positive, it is essential that the temperature of the target face be well below the point where appreciable electron emission takes place from it with resultant bombardment of the filament by the inverse current. It is not unusual for the x-ray tube to be completely destroyed by operation under these conditions and it is therefore necessary to limit the current-carrying capacity of the tube to considerably less than that which would be possible in the type of circuit where voltage reversal does not occur across the x-ray tube. A second factor limiting the capacity of the tube in the self-rectified circuit is the relationship of the average current as read on the milliammeter (I_{av}) to the peak current (I_m) which the focal area must dissipate. As shown in Figure H the ordinate representing the average current is derived from spreading out over a full cycle,

time t_2, the area of the current-time curve over the useful half cycle, time t_1. For half-rectified sine wave, the ratio of average to maximum values is

$$I_{max} = 3.14\ I_{av}$$

The focal area must be sufficiently large to withstand an instantaneous current of more than three times the values indicated on the milliammeter.

RECTIFICATION AND X-RAY TUBE RATINGS - If both halves of the voltage could be utilized, the ratio would be $I_{max} = 1.57\ I_{av}$ so that the focal area would stand a maximum instantaneous value of less than twice the average value as read on the milliammeter. We would expect, then, that the tube ratings for the same focal areas will be substantially less for the self-rectified circuit than they might be for a circuit in which the anode potential remained positive for both half cycles; the full-wave rectified. Figure I shows the comparative ratings for the DX2.0-4.5 tube for various times in which the relative currents clearly are indicated. It is seen

CURRENT (MA) AT 80 KVP

2.0 MM FOCUS

	1/10 SEC.	1 SEC.	10 SEC.	30 SEC.
SELF-RECT.	34	30	25	20
FULL-WAVE	70	52	35	25

4.5 MM FOCUS

SELF-RECT.	115	85	50	35
FULL-WAVE	240	150	75	40

Figure I

that for the very short exposures, 1/10 second, the ratio of current ratings is almost exactly 2 to 1, as would be expected because of the high temperatures associated with short exposures and the limitation imposed by the maximum value of the current, the ratio of the relative maximum for the two circuits being also two to one. For the longer exposures, the effects of the maximum current are less and the heat capacity and radiating ability of the entire anode affect the relationship, tending to average out the differences with longer exposures. In the 30-second column, for example, the difference of current ratings is not more than 20 per cent while the longer fluoroscopic current ratings are the same for all circuits. Figure J illustrates a more common form of a rating chart.

Despite the disadvantage of requiring somewhat larger focal areas for comparable ratings, the self-rectified circuit is extensively employed because of its

simplicity, economy, and light weight for portable, mobile, and stationary diagnostic x-ray machines up to and including 100 ma. units. For the more powerful units, the increase in focal-spot size becomes an objectionable factor because of the effect on geometrical unsharpness of the radiographic image.

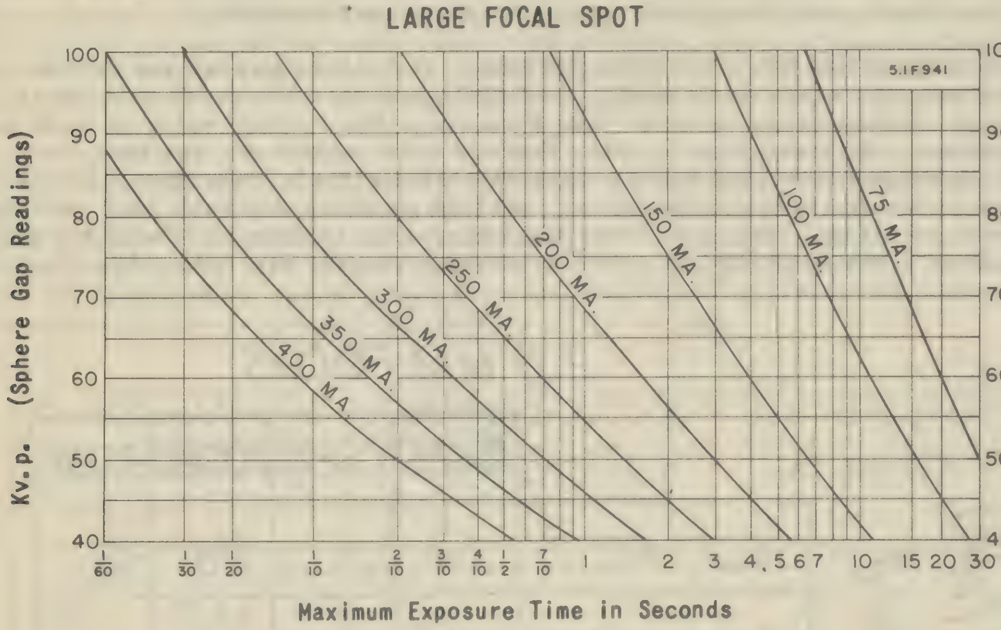


Figure J

For this reason, it is necessary to utilize an apparatus which can be connected between the high-tension transformer terminals, (X) and (Y) of Figure G and the x-ray tube and which will automatically function to maintain the anode potential positive and the cathode potential negative. Under these conditions the x-ray tube will permit a flow of current for successive half cycles and both will be utilized for the production of x-rays. The peak emission for a given average current will be half that of the self-rectified circuit and the tube rating will be greatly increased, particularly for the shorter exposure times. The agency by which this end is accomplished is the high-voltage rectifier, of which the valve tube is the basic element in all modern x-ray generators.

VALVE TUBES - The valve tube is a two-element hot-cathode vacuum tube which, in general principle, is not unlike the x-ray tube itself in that a thermiontic current is conducted through the tube when the anode is positive with respect to the cathode, the current ceasing when the polarity is reversed.

Unlike the x-ray tube, the electron emission from the filament of a valve tube is in excess of that required by loading conditions on the output circuit so that with proper design of the anode and cathode to minimize space charge, the voltage drop across the tube need not be more than 2 to 4 KV.P. The current limitation due to space charge is quite different from the current limit of the x-ray tube which is determined by the electron emission from the filament, practically all available electrons being drawn across to the anode.

Other requirements of the vacuum tube rectifier are the ability to withstand high voltages, freedom from erratic electrostatic charges on the inner surfaces during operation, and the capacity to operate at high cathode temperatures without

liberation of gases. The most common circuit for x-ray rectifiers used in medical diagnostic applications is the full-wave bridge arrangement of Figure K in which four valve tubes are used, each connected to filament transformers which are omitted from the diagram in the interest of simplification.

The voltage across the terminals (X) and (Y) is an alternating voltage as

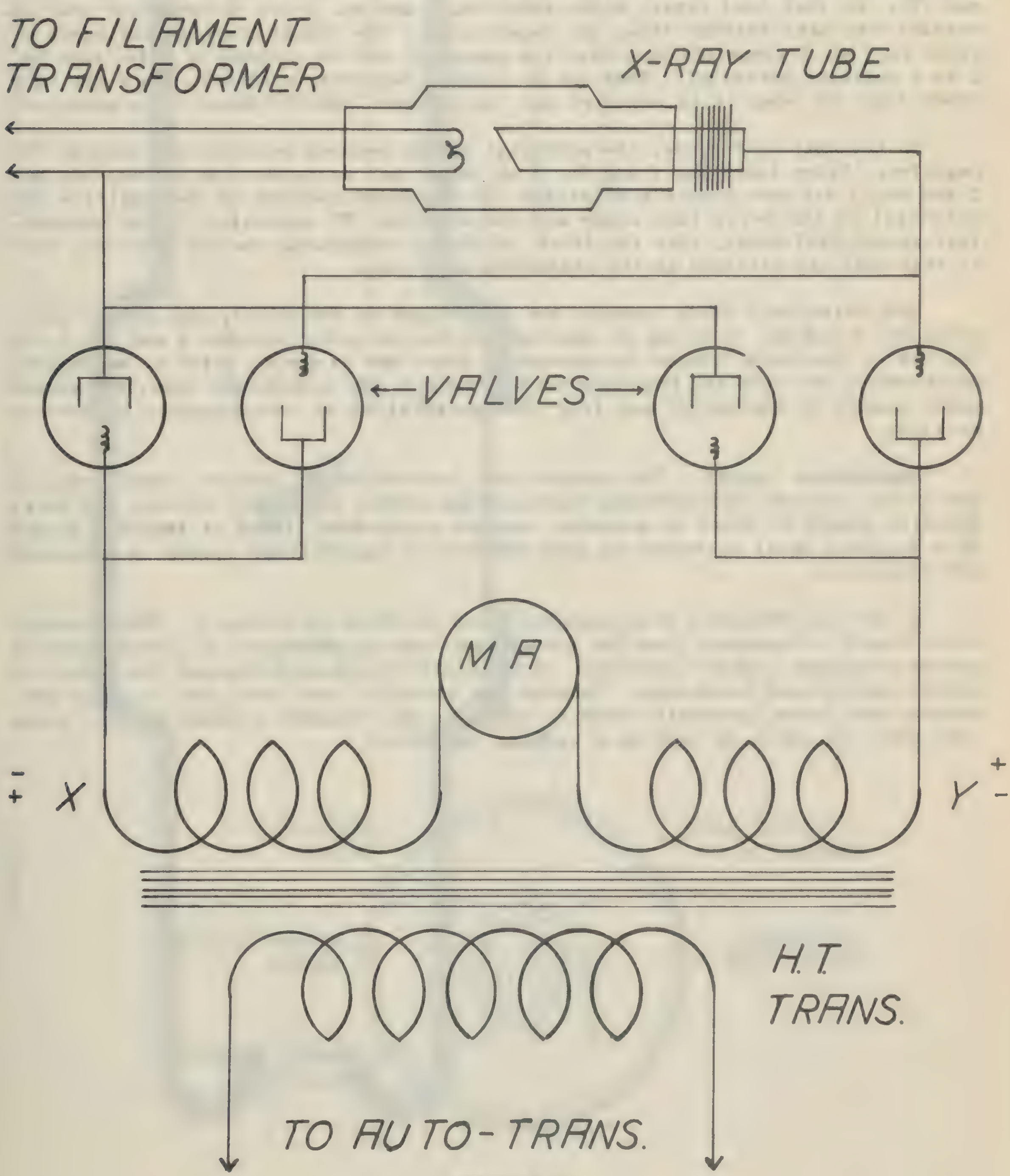


Figure K

previously described, the polarity changing each half cycle which for 60-cycle supply is 1/120 second. Assume first that (Y) is positive and (X) is negative. The anode of valve tube No. 4 is connected then to the highest positive potential and the cathode of valve tube No. 1 to the highest negative potential in the circuit. A current will then flow through these two tubes with very little voltage drop, bringing the terminals of the x-ray tube to essentially the same potential as points (X) and (Y). On this half cycle, valve tubes No. 2 and No. 3 are so connected that no current can pass through them, an inspection of the figure showing the anode of valve tube No. 2 connected to a negative potential and the cathode of valve tube No. 3 to a positive potential. They act as current barriers to isolate the x-ray tube anode from (X) when it is negative and the cathode from (Y) when it is positive.

On the next half cycle, the potential of (X) becomes positive and that of (Y) negative. Valve tubes No. 1 and No. 4 no longer act as conducting valves, but No. 2 and No. 3 are now properly polarized for the establishment of the positive (X) potential on the x-ray tube anode and the negative (Y) potential on the cathode. This second half cycle, like the first, is then a conducting one for the x-ray tube so that both are utilized in the production of x-rays.

The third half cycle repeats the conditions of the first, and so on, valve tubes No. 1 and No. 4 acting in combination for one pulse and No. 2 and No. 3 for the next. The rectification is noiseless, there are no moving parts or mechanical adjustments, and with oil immersion of the tubes in the transformer tank, the entire power supply is shockproof and free from possibility of contamination by dust or moisture.

SHOCKPROOF CABLES - The connections from the high-tension transformer to the x-ray tube are made through high-voltage rubber insulated cables, the outer metallic sheath of which is grounded, and the x-ray tube itself is immersed in oil in a grounded metal container so that the entire high voltage system is protected and shockproof.

A section through a high-tension cable is shown in Figure L. The grounded metal sheath is separated from the actual high-tension conductors by a high grade of corona-resistant rubber insulation, sufficiently thick to withstand the potential difference without breakdown. Through the center of the core, two or three conductors are found, generally used to complete the filament circuit to the x-ray tube when the cable is used as a cathode connector.

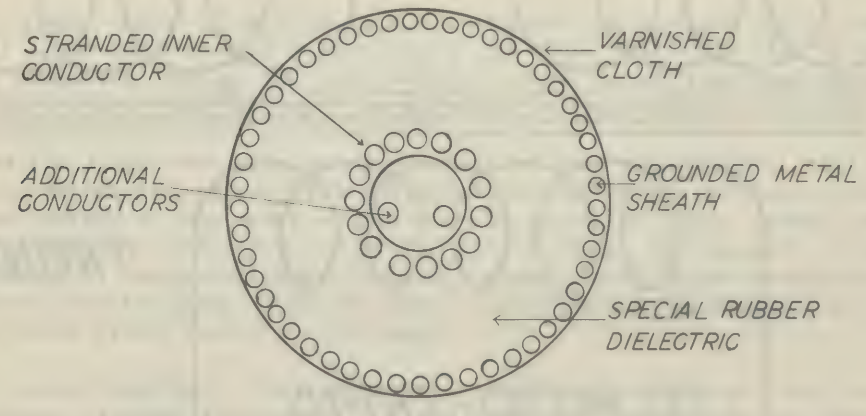


Figure L

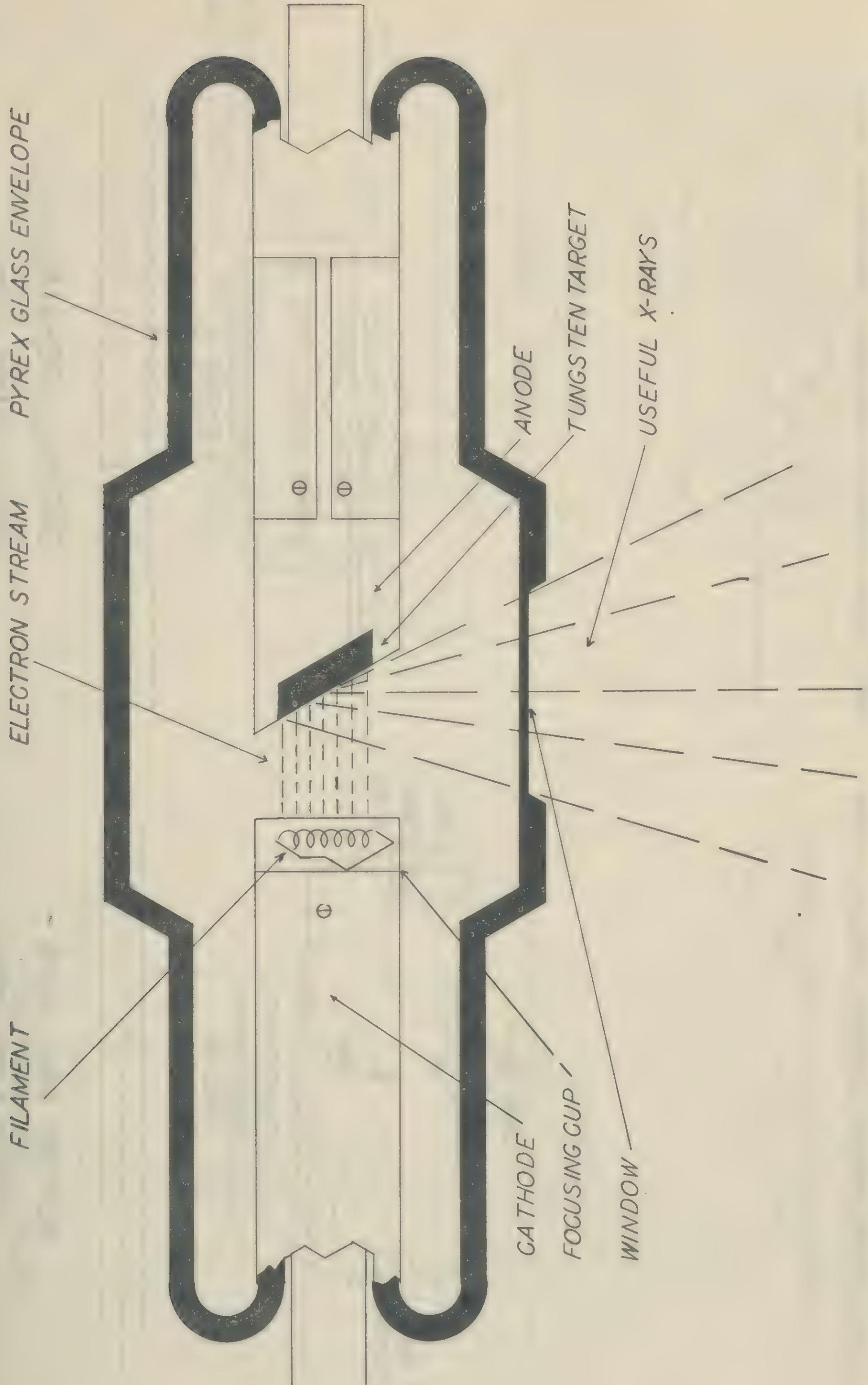
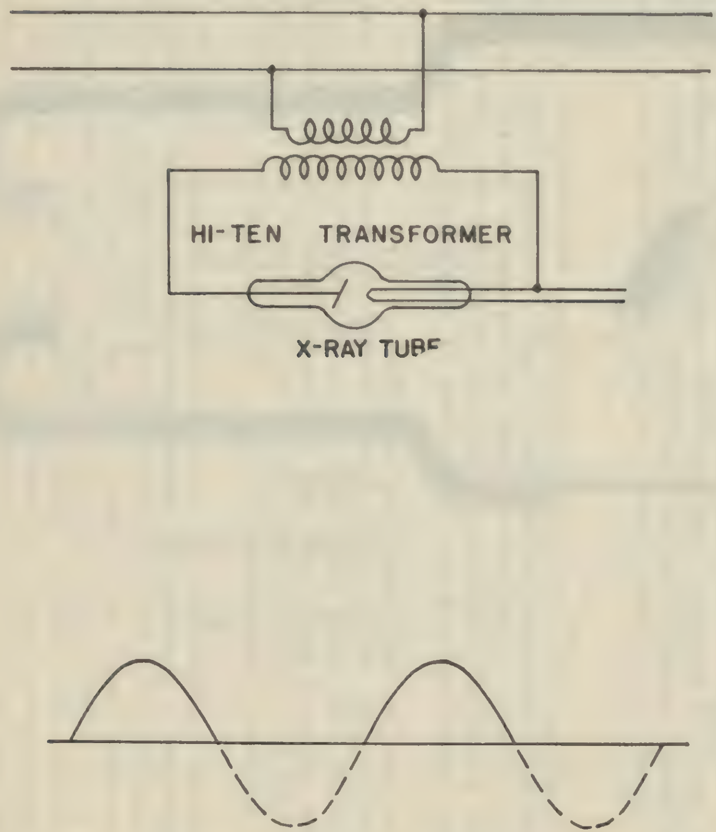

PYREX GLASS ENVELOPE
ELECTRON STREAM
FILAMENT
ANODE
TUNGSTEN TARGET
USEFUL X-RAYS
CATHODE
FOCUSING CUP
WINDOW

Figure M

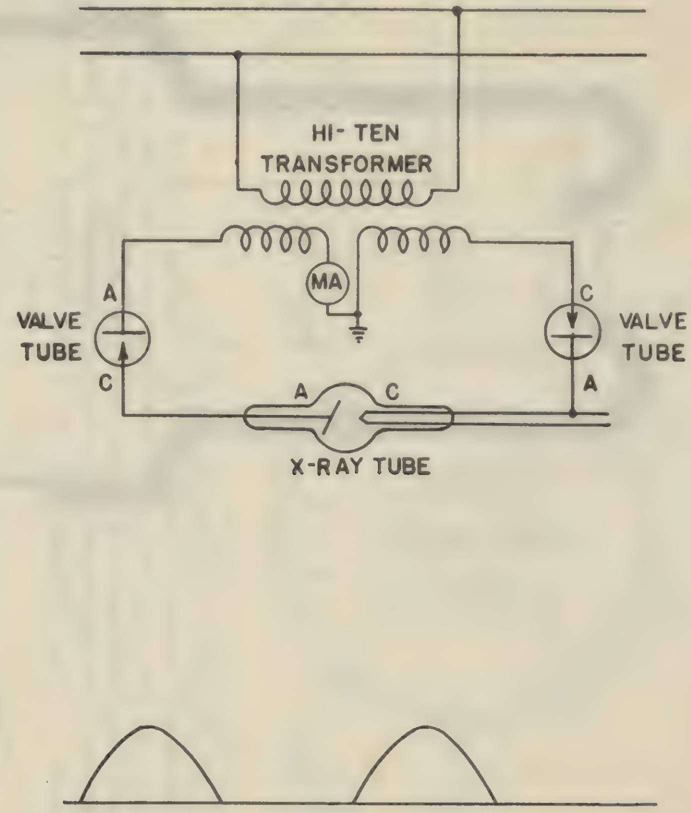
HALF WAVE CIRCUIT
WITHOUT VALVE



PATH OF VOLTAGE TRAVERSED IN ABOVE CIRCUIT. DUE TO THE VALVE EFFECT OF THE TUBE, THERE IS NO CURRENT FLOW DURING LOWER HALF-WAVE

Figure N

HALF WAVE CIRCUIT
WITH TWO VALVES



PATH OF VOLTAGE TRAVERSED IN ABOVE CIRCUIT. THE LOWER HALF-WAVES SUPPRESSED BY THE VALVE TUBES PRECEDING THE X-RAY TUBE

Figure O

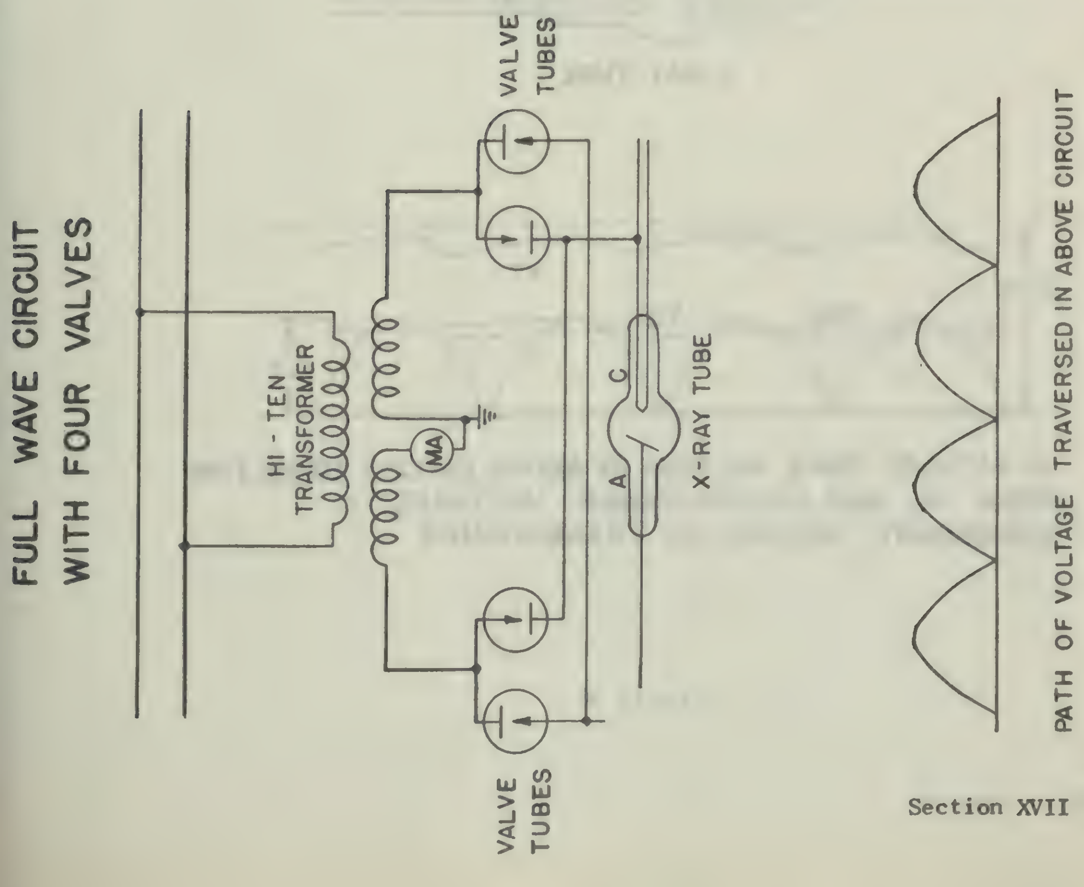


Figure P

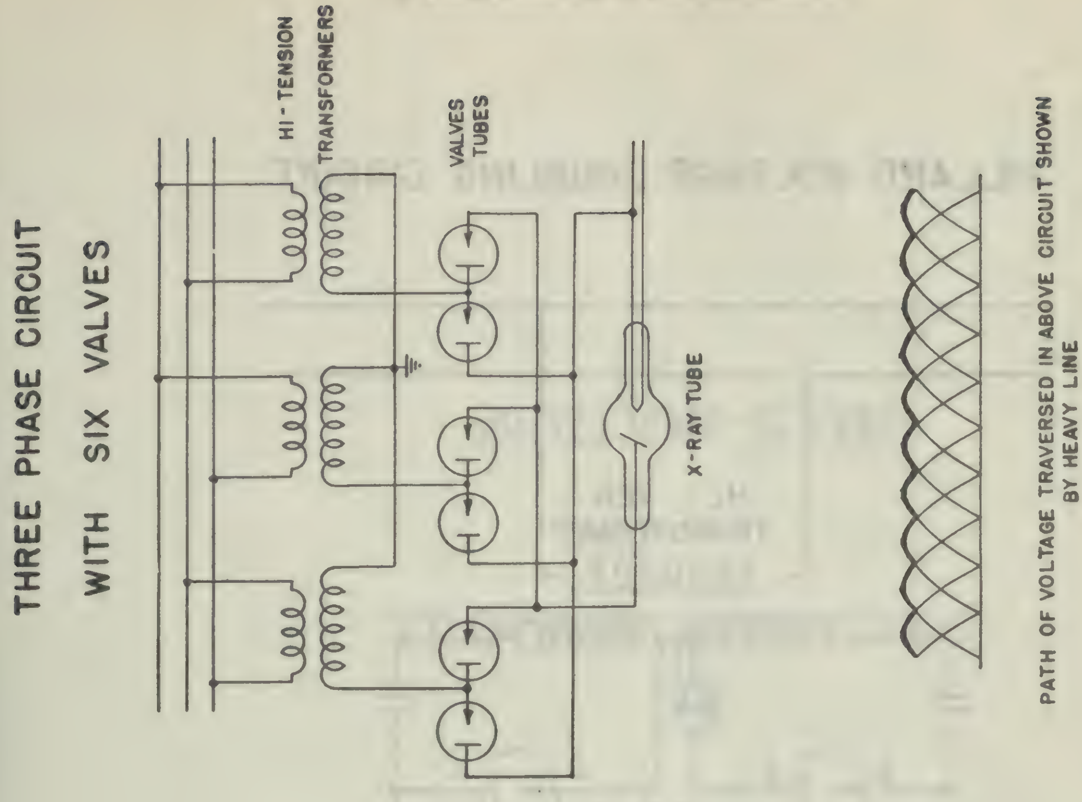
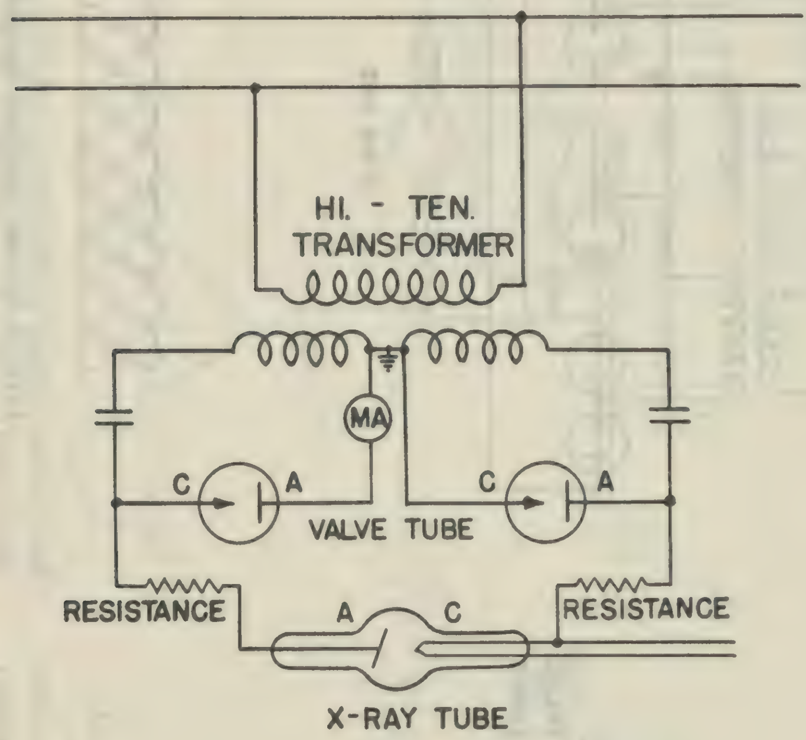
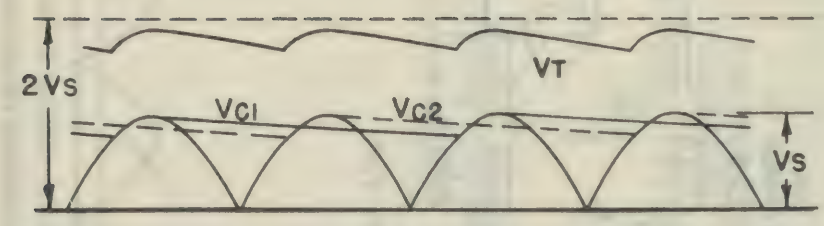


Figure Q

VILLARD VOLTAGE DOUBLING CIRCUIT





V_T PATH OF TUBE VOLTAGE IN ABOVE CIRCUIT RESULTING FROM V_{C1} AND V_{C2} CONDENSER VOLTAGES V SECONDARY VOLTAGE OF TRANSFORMER

Figure R

SECTION XVIII

TROUBLE SHOOTING

TROUBLE SHOOTING

A service call does not necessarily mean that the unit in question will require major repairs. The majority of service calls are for repairs of a minor nature.

All x-ray equipment operates on the same basic principle. All units have an oil immersed transformer for the high tension voltage supply and a step down transformer for the filament current. Some units use an auto transformer to control kilovoltage, and as a source of current for auxiliary circuits. In some of the smaller units, the kilovoltage is controlled by means of a series of taps on the various turns of the primary coil in the high tension transformer. Impressing a fixed voltage on more or less turns on the high tension transformer primary, changes the ratio of primary to secondary turns. As this ratio changes, the kilovoltage (or output voltage) also changes, for example: If the incoming line voltage of 110 volts is impressed across the entire high tension primary winding, 1100 turns for example, the high tension secondary voltage may be approximately 45 K.V.P. If the same voltage (110) was applied to only 1/2 of the primary turns (550), the kilovoltage across the high tension secondary will be approximately double or 90 K.V.P. This change in output voltage is the result of the change in the ratio between the primary and the secondary coils.

Before attempting to repair any machine, first inquire of the operator as to the nature of the difficulty and determine the manner in which the unit operated prior to the time of the failure. A case history of the operation prior to failure may save considerable time in finding the source of trouble.

If the apparatus fails to produce x-rays and the difficulty is not apparent, that is; there is no smoke, arcing or sparkovers inside either the tube head or the transformer it will be necessary to find the difficulty through a process of elimination. Determine which main circuit is involved; the primary control circuit, the secondary high tension circuit, or any of the auxiliary control circuits.

A high resistant voltmeter (1000 ohms per volt) is an ideal meter to use for trouble shooting. If such a meter is not available a test lamp made with a regular lamp socket and two leads, approximately 15 inches long, will be found useful.

If the difficulty cannot be detected by sight or sound, then, with the unit turned on (no high tension) and with all controls at the minimum settings, the following procedure is suggested. From the wiring diagram, determine the terminals of the primary of the high tension transformer at both the control and transformer. Place the voltmeter, or trouble light leads across the high tension <u>primary</u> terminals in the control. When the foot switch or push button control device circuit is closed, the test voltmeter or light should indicate. If the meter does not read or the bulb does not light, the trouble will be found in the control stand. If the meter or light does indicate that voltage is present, the difficulty will be located at some point after the high tension primary terminals in control stand. Place the voltmeter leads on the terminals of the high tension primary coil at the transformer. If no indication is obtained when the push button or foot switch is depressed and the corresponding terminals in the control did provide an indication, then it is apparent that the difficulty lies between the control and the transformer. The inter-connecting wiring must be examined closely. Check the copper lugs, plugs and various connections of the inter-connecting cable carefully.

Should the x-ray tube filament fail to light, determine that voltage is being obtained in this circuit. Using the wiring diagram of that particular equipment, check all points in this circuit.

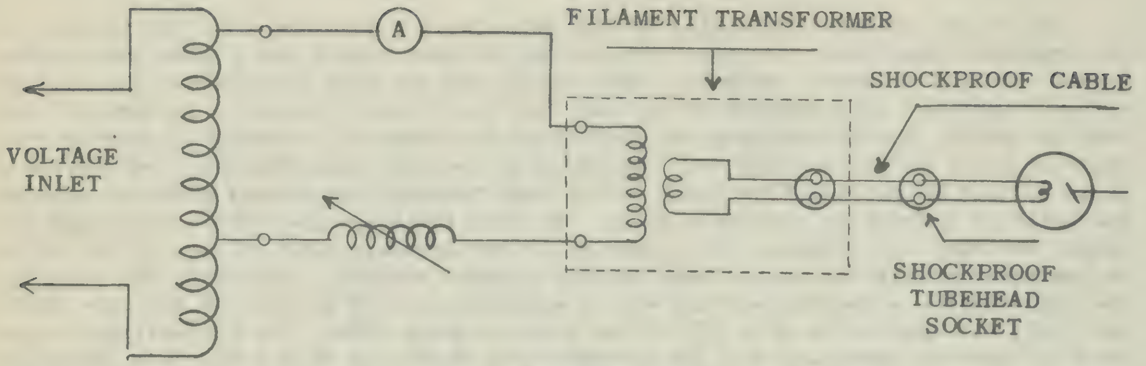


FIGURE A

The above illustration shows a common x-ray tube filament circuit, including an auto-transformer, filament regulator, filament ammeter, and it is not intended to illustrate any one manufacturer's apparatus.

Assume the problem is to determine why the filament of the x-ray tube does not light. The first step in the majority of cases would be to remove the end of the shockproof cable that fits into the tubehead. Connect a low reading voltmeter across the terminals at the end of the cable. Do not energize the high tension x-ray circuit during this test. If a reading is not obtained on the voltmeter it indicates the difficulty is at some point between the cable end and the incoming voltage source. If a reading is obtained, it means the fault is between the cable end and the filament of the tube itself. If no low scale voltmeter is available, then by shorting the filament prongs on the end of the cable with a small screwdriver or other small metal tool, sparking will indicate that voltage is present.

With voltage present at the cable end, suspect poor filament contact between the cable end and the receptacle of the tubehead, or a broken wire from the base of the receptacle, or an open circuit in the filament of the tube itself.

When no voltage is present at the cable end, determine what part of the circuit is at fault. Make certain that the incoming voltage is correct. Check the voltage across the incoming line studs in the control. Then check the voltage at the primary of the step down (filament) transformer and if no voltmeter reading is obtained, then the fault is between the terminals on the primary side of the step down transformer and the source of the inlet voltage. If the various component parts of this circuit are accessible, the problem of locating the defective part is simple. By placing a voltmeter across the ammeter no reading should be obtained. If a voltmeter reading is obtained, this is an indication that the ammeter has failed. The same procedure will apply when checking the filament regulator. When the voltmeter leads are placed on the terminals of the filament regulator and a reading is obtained on the voltmeter, it is evident that the filament regulator has an open circuit.

When the various devices that make up the complete circuit are not readily accessible, each portion of the circuit should be isolated to simplify the problem.

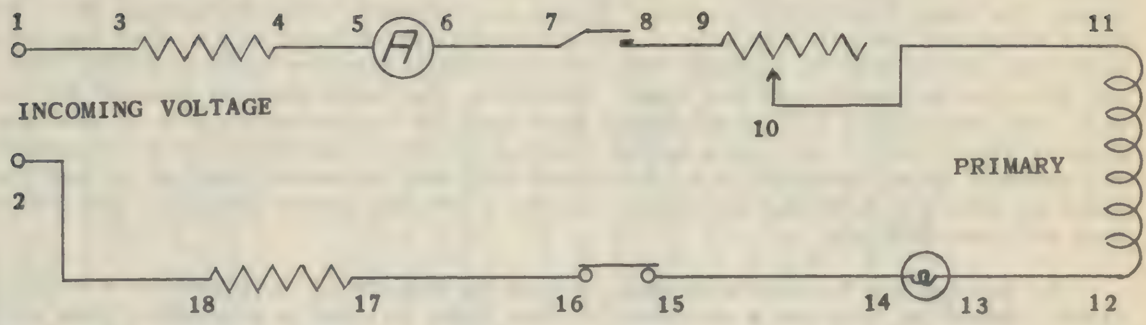


FIGURE B

In the above figure assume that there is a defect somewhere in the circuit. The nature of this fault is an open circuit. Various parts of the circuit are not readily accessible.

Using a voltmeter, determine what portion of the circuit is open. Proceed as follows: Place the voltmeter leads on terminals #1 and #11, no reading should be obtained. If the voltmeter indicates, an open circuit will be found between points #1 and #11. Assuming a voltmeter reading is obtained, then with one voltmeter lead on either terminal #1 or #11, progressively move the other lead along the circuit until a point where no reading is obtained.

To clarify further, suppose one voltmeter lead is fastened to terminal #1. Then move the other voltmeter lead from #11 to #10; if a reading is still obtained on the voltmeter it indicates the circuit from #11 to #10 is complete. Next move the lead to terminal #9, if no reading is obtained, that immediately shows the rheostat (terminals #9 and #10) is the device having the open circuit.

From Figure B it will be seen, if no open circuit were present between terminals #1 and #11, the voltmeter would actually be across one side of the circuit only. The meter has a comparatively high resistance and the component parts of the circuit itself are of a low resistance. Thus, the path of flow will be through the lowest resistance path. No voltmeter readings will be obtained while the low resistance path is complete. When a break takes place at any point in the low resistance circuit, a voltmeter reading is obtained at any place on either side of the break.

Again referring to Figure B, suppose a break were encountered in the primary coil (#11 and #12). A voltmeter across these terminals will give an indication. The check of the continuity of the circuit through the primary coil is also quite simple. In Figure B, if tests made from #1 to #11 show this circuit is complete, tests from #12 to #2 also show that portion of the circuit is complete, then suspect the primary coil. By opening the connection at 12 and placing a voltmeter lead at the open coil end and the other on terminal #2, a reading on the voltmeter should be obtained. If a reading is not obtained then the primary coil is open-circuited.

It is possible to have the voltmeter arranged to indicate when the circuit is completed. For example, again using Figure B, assume the contacts 16 and 15 fail to close. To trace this trouble, simply fasten one voltmeter lead to terminal #1. The other voltmeter lead will then be placed in succession on terminals 2 where the meter will read, as it will on terminal #18, #17, and #16. When the lead is put on terminal #15, the voltmeter will not read. Therefore, the break must be between #16 and #15. The meter does not read because both legs of the voltmeter are on the same side of the circuit. In other words, one leg of the inlet power source (terminal #1) extends up to terminal #15, therefore with one voltmeter lead on #1 and the other on #15, the voltmeter is shunted across a low resistance conductor and therefore will not indicate.

It is possible to locate an open circuit by means of a voltmeter or a trouble light. Depending upon how a voltmeter or test light is used in a circuit, they will indicate when the difficulty is located, or they can be used in a manner that they fail to indicate when the difficulty is encountered.

A simple plan to follow, tracing a service problem, is to draw a diagram of the circuit in which the trouble has been found. This eliminates the remaining parts of the apparatus and aids one to visualize what occurs as the voltmeter or trouble light leads are moved from point to point. Do not expect a light bulb to light if it is only in one side of the power line. A grounded circuit is one side of a circuit that has a low resistance path provided to ground. Generally, a grounded circuit will cause a fuse or circuit break to open; many times the point where the circuit is grounded will either arc or flame. Quite often it is only necessary to provide insulation at this point and reset the circuit breaker or replace the fuse.

It is difficult to outline a procedure to locate trouble that would apply to all makes and types of X-ray apparatus. In spite of the fact that all manufacturers follow the same general pattern and designs, there are enough variations in terminal designations and circuits to make impractical, a standard trouble-shooting chart that would apply to all apparatus. The chart that follows does not apply to any particular make of equipment. It has been compiled as a guide for x-ray service men. Realize, many circuits do not have various parts mentioned on the chart, other circuits will not have materials or devices indicated.

GUIDE TO LOCATING X-RAY APPARATUS SERVICE TROUBLE

APPARATUS FAULT	PART SUSPECTED	POSSIBLE TYPE OF DEFECT	SUGGESTED PROCEDURE TO LOCATE FAULT
No incoming voltage at control stand.	Power voltage failure		Use test voltmeter or trouble lamp across line terminals.
	Line voltage or compensator switch.	Open circuit--switch on a dead button.	Move switch--examine connections and wiring--clean up.
	Main line fuses.	Fuses open circuited.	Using light or test voltmeter--check both ends of fuses.
	Main switch.	Mechanically defective.	Check operation of switch mechanically. Make certain full
		Poor contact.	surface contact between stationary and moving contacts on switch.
	Control stand ON-OFF switch.	Mechanical defect--open circuit.	Use test voltmeter. With switch "ON", readings on both sides of switch should be similar.
	Cable from fuse box to control.	Open circuit.	A voltmeter across the fuses should read the same as when placed across to line terminals of the control.
	Line voltage adjustment strap.	Poor contact or open circuit.	Tighten terminals or fastening nuts. Place voltmeter leads on either end of strap. No reading should be obtained.
No X-ray obtainable.	Push button or foot switch.	Burned out contacts.	Short contacts mechanically.
		Broken wire in cable.	Move cable around, trying to obtain contact--use voltmeter
		Connecting plug not making contact.	--examine plug--clean contacts and tighten--tighten terminals.
	Contactor--(oil immersed, single or double air type).	Coil open circuited.	Can be seen or heard when push button operated.
		Contacts not closing.	Place voltmeter leads across the normally open contacts of contactor. Meter *should* read when contactor is *not* energized, should *not* when button is closed.
		Open-circuit between auto and high tension primary coil.	Use voltmeter or light test to locate point of open circuit.
		Circuit to contact coil opened.	Using wiring diagram and voltmeter, trace open circuit.
		Lead resistance opened.	Voltmeter leads on each end of resistance should *not* read when load is applied.
	K. V. adjustments, line, or M. A. load compensator tap switch.	Brush contact not making properly.	Visual examination, or place low reading voltmeter leads, one on the contact and the other on the brush. No reading should be obtained, under load conditions.
			Move switch to another button, then test.
		Broken wire from auto to bottom of tap switch.	Use wiring diagram and voltmeter to locate point of break.
		Open circuit between auto and tap switch.	
		H. T. primary coil *Open circuited*.	Apply a low voltage direct from the auto to test. Note: Be sure the M.A. lead of the H.T. transformer is grounded.
	Shock-proof cable	Broken down.	Generally visible or can be heard. Blows fuses or breaker.
			Remove one cable at a time to test.
		Grounded.	Removing the defective cable clears up trouble.
		Improper installation.	Visual examination or reverse the cables, if possible.
		Carbonize path in cable receptacle, or on cable and fittings.	Visual examination, generally can be heard. To test, remove cable, place on insulated platform and apply high tension between the grounded braid and the center leads.
	X-ray tube.	Tube punctured.	Apparatus draws excessive current. Remove tube from unit. Tube will glow bright blue color. Oil in tube. Filament oxidized.
		Filament not lighted.	See suggestions below.
		Sparkover inside tube head.	See suggestions below.

APPARATUS FAULT	PART SUSPECTED	POSSIBLE TYPE OF DEFECT	SUGGESTED PROCEDURE TO LOCATE FAULT
	High Tension Transformer	Broken down secondaries.	Sparkover can be heard. Smoke emitted from transformer vent.
		Open circuit primary.	Use voltmeter or test light to check--apply low voltage on primary.
		Loose wire inside transformer.	Visual examination--test meter--tighten all terminals.
(Cont.) No X-ray obtainable.		Insulation breakdown.	Generally audible or visible. Check insulation, using ohmmeter to determine leakage path resistance.
	Auxiliary or safety circuits.	Contacts on special devices not operating properly.	Consult manufacturing instruction and blue print data for information both as to operation and methods of correcting faults.
	Timer circuit.	Motor not running. Contacts not opening or closing.	Check motor wires--voltage to motor. Visual examination or test meter.
		Friction clutch slipping.	Visual or manual check.
		Relays not operating.	Voltage test or visual examination.
		Broken wire in timer, not hooked up properly.	Follow circuit and blue print and test meter. Check circuit and manufacturing instructions.
		Overload breaker open.	Reset.
		Machine set incorrectly.	Review data supplied with apparatus.
		Cables not attached.	Recheck.
		Fuses burned out.	Test--using voltmeter.
	Incoming power source inadequate.	Wires to the fuse box too small.	Wire gets warm--voltmeter at fuse box shows large drop under load.
		Wires from fuse box to control too small.	Wire gets warm--voltmeter at control line terminals shows excessive drop.
		Power transformer or source inadequate.	Excessive line voltage drop.
		Knife switch too small.	Excessive voltmeter variation between inlet and outlet side of switch.
		Any portion of circuit connected by too small wire.	A voltmeter connected between any two parts of a circuit. should *not* read--wire gets warm.
		Holding screws or nuts not tight.	Use voltmeter to check drop between the two parts.
	Poor Contact.	Contact brushes to tap switches burned excessively.	Visual examination--voltmeter between tap and brush will read when it should *not*. This test made under load conditions.
Excessive drop. or rise in K. V. or M. A. also- Inability to secure full capacity of apparatus.		Contactor primary contacts burned excessively.	Visual examination--voltmeter test between contacts, meter should *not* read under load.
		Carbonized path to ground.	Generally can be seen or heard or be detected by the sense of smell.
		Carbonized path shorting two portions of the circuit.	Blows fuses and generally burns out wire or part of circuit shorted.
	Transformer or tube breakdown.	Air in tube.	Causes M. A. to deflect full scale--tube flashes a blue color.
		H. T. secondary breakdown.	Arcing inside transformer or smoke from transformer.
		Short in H. T. Primary.	Primary current (amperage) will be excessive. K.V. will increase.
		Insulation breakdown inside transformer.	Arc-over inside transformer--smoke from transformer.
		Sparkover inside shockproof cable fittings or cable receptacles.	Generally can be heard. Evidence is small black burned spots on surface, or long jagged carbon paths to nearest grounded point.
		Tubehead insulation failure.	Generally can be heard, and located by visual examination.
		Open or short circuit under oil.	If open, sparkover can be heard. If shorted, will manifest itself by excessive current drain or overheating.

APPARATUS FAULT	PART SUSPECTED	POSSIBLE TYPE OF DEFECT	SUGGESTED PROCEDURE TO LOCATE FAULT
(Cont.) Excessive drop or rise in K.V. or M.A. also- Inability to secure full capacity of apparatus.	(Cont.) Transformer or tube breakdown.	Excessive resistance in H. T. primary circuit.	A voltmeter across the H. T. primary terminal will show an excessive drop under load.
		Low valve tube heat.	Shortage of M A.-valve tube will emit X-rays--valve anode overheat.
Filament of X-ray tube not lighted.	X-ray tube.	Tube filament open circuited.	Test with ohmmeter--apply a low voltage direct to filament--(warning) use 12 volts or less.
		Cathode cable conductor open.	Use series light, ohmmeter or voltmeter to test continuity.
	Shock-proof cable.	Poor contact between cable end and socket.	Shift cable in socket--Bend contacts at end of cable.
	H.T. transformer.	Filament secondary circuit open or shorted.	Test, using ohmmeter, voltmeter or series light--if partially shorted the secondary will overheat and not deliver enough voltage.
	Control stand.	Filament prereading ammeter.	Test using voltmeter--the test meter, placed across the ammeter should not read.
		Filament regulator open.	Test using voltmeter--the test meter placed across the regulator should not read.
		Limiting resistor open.	Test using voltmeter--the test meter placed across the resistor should not read.
		Safety device not operating.	See manufacturing instructions and blue prints for details.
		Filament changeover device not operating.	Use voltmeter or visual examination.
		Focus pilot light burned out.	Replace with good lamp--use voltmeter to test.
		Circuit between auto and filament primary coil open.	Check using blue print and test voltmeter.
M.A. meter not functioning.	Meter	Burned out, or shorted.	X-ray coming from tube but meter does not operate.
	Meter condenser.	Shorted.	Cutting condenser out of circuit will make meter read correctly.
	Tube	Circuit defective.	No X-rays from tubes.
	Tube	Filament not lighted.	See previous suggestions.
M.A. meter indicates but in a fluctuating manner.	Line voltage.	Varying.	M.A. meter and control voltmeter fluctuates at the same time and same rate--correct line condition if possible.
	X-ray tube.	Gas or air in tube.	Blue glow in tube--M.A. will oft times go beyond the scale range.
	Filament circuit.	Loose connection.	Tighten all filament connections. Use test voltmeter.
	X-ray tube.	Loose connection in tube.	Jar tubehead by hand to detect any change in M. A.
	Shock proof cable.	Poor contact between cable and cable socket.	Tighten up contacts--Shift position or move cable to detect any change in M. A. meter reading.
Circuit breaker or overload device kicks out.	X-ray tube.	Punctured.	Remove cables, which will then permit voltage to be applied to machine without circuit breaker kicking out.

APPARATUS FAULT	PART SUSPECTED	POSSIBLE TYPE OF DEFECT	SUGGESTED PROCEDURE TO LOCATE FAULT
(Cont.)	S. P. Cables.	Broken down.	Generally can be seen. Remove one cable at a time to check.
Circuit breaker	X-ray apparatus.	Grounded.	Sometimes accompanied by arc-over--visual examination.
or overload device	X-ray apparatus.	Shorted.	A portion of the circuit becomes overheated-- arcing.
kicks out.	Insulation.	Broken down.	Generally can be seen or heard--Insulator will become warm.
	Apparatus.	Being overloaded.	Check manufacturing ratings of apparatus--Check that incoming line voltage is proper for the machine.
	X-ray or valve tubes.	Faulty technique.	Take a radiograph with known factors.
		Dark room procedure.	Check strength of chemicals--Check dark room timer-screens, cassette contact--faulty film.
		Incorrect time.	Make spin top test.
	Valve tubes.	Valves N.G.	Check valve filament heat, make sure all valves are lighted.
Light films.		Insufficient K.V.	Make a ladder or comparative density test.
		Gas.	Watch tube and valves during operation for blue colored flashes indicating gas--M.A. meter will jump up.
		Filament heat too low.	Insufficient valve filament heat will prevent full amount of M.A. from getting to X-ray tube--Follow manufacturing directions for setting valve filaments heat correctly.

SECTION XIX

HANDLING AND USE OF INSULATING OILS IN X-RAY APPARATUS

HANDLING AND USE OF INSULATING OILS IN X-RAY APPARATUS - The use of oil in x-ray apparatus is for two purposes, for insulation, or as a cooling medium, or both. As oils in general are extremely complex organic compounds, their efficiency may be impaired by a large variety of factors and great care must be exercised in their handling.

In transformers, oil with high dielectric strength must be used to prevent grounding or spark-over of the coils. In tubeheads, it serves as an insulating material between the tube and surrounding parts, and it also serves as a cooling medium.

DIELECTRIC STRENGTH - Fortunately, the factors which destroy the dielectric strength (the insulating property of the oil) also affect its efficiency as a cooling medium. Therefore, the same factors are considered when the oil is used for either purpose.

These factors (three main causes of failure) may be divided as follows, first, moisture; second, deterioration; and third, foreign material.

MOISTURE - As the slightest amount of moisture destroys the dielectric strength of transformer oil, it is highly dehydrated in refining. It has an affinity for water moisture, consequently great care must be used to keep it in its original moisture-free state. To do this, many precautions are necessary.

If the room temperature is higher than the temperature of the oil, the temperature of the oil should be brought up to or above the room temperature before opening the container. Closed containers of oil can be warmed by placing them near a radiator or in the sun. The implements used should have the same temperature as the room.

Oil will actually absorb water vapor and condense moisture from the surrounding atmosphere at a relatively rapid rate. Under no circumstances should oil be handled, or containers be opened, when the relative humidity is 50% or higher. Oil will collect moisture as a result of any sudden changes in temperature. This takes place when compressed air is used to clean containers or receptacles. Even the small amount of air that leaks into the drum (or can) as the oil runs out may contain sufficient moisture to cause a reduction of its dielectric strength. For this reason a so-called calcium chloride breather unit should be used on large drums or storage tanks from which oil is periodically drawn. It is recommended that oil to be used as replenishing oil for coolers or transformers be kept in sealed 1 or 5-gallon cans and that the entire can be used at one time. Because there is always more or less air in the container, it should never be stored where it undergoes great changes in temperature, such as near steam pipes, radiators, etc.

DETERIORATION - Oil deteriorates very slowly but nevertheless deterioration does occur under the best conditions. The rate of deterioration is accelerated by such things as high temperatures, the presence of moisture, oxygen or certain foreign bodies which act as catalyzers. This process results in the formation of alcohols, esters, acids, and finally soaps which produce sludge. Sludge breaks down the dielectric strength as well as lessening the cooling efficiency. Spark-over, which carbonizes the oil, is a great factor in deterioration.

The backs of the anodes of deep therapy tubes that employ oil as a cooling agent, which have been overloaded or operated with oil of poor quality usually have a pronounced carbon deposit. This will eventually lead to tube failure because the heat cannot be removed fast enough from the anode through the film of carbon to keep

the anode temperature below the melting point.

One of the large number of agents that causes deterioration is rubber. Consequently, rubber containers, tubing, etc. should never be used.

FOREIGN MATERIALS - As foreign materials form a great group of offenders, they are listed below, and extra care should be used to prevent their introduction into the oil.

1. soldering flux
2. cleaning fluids
3. lint
4. dust
5. emery
6. steel
7. rubber
8. cement
9. ordinary gasket fibers
10. cork

All soldering flux should be avoided, if at all possible. It is practically impossible to thoroughly clean the joint after a flux has been used. When it is necessary to use solder, a fluid resin should be used. This may be removed by use of dry white gasoline (not ethyl). Use a *clean chamois skin* for wiping surfaces which come in contact with oil. Rags will generally leave threads or lint on the surfaces. Emery or steel wool should never be used. If the use of an abrasive is necessary, sandpaper is recommended.

When varnish, shellac, or similar compounds are used on transformer windings, tanks, tubeheads, etc., they must be properly cured by oven baking before coming in contact with oil. Gaskets, pump packings, varnishes, or cements other than those specifically approved by the manufacturers should be avoided. Only copper backed gaskets (spark plug type) should be used for oil line connections on shockproof deep therapy equipment. When using cements around gaskets, line connections, etc., excessive amounts should be avoided. The surplus should always be removed and before it comes in contact with the oil it should dry overnight at room temperature, or if heat drying is available, it should be subjected to not less than four hours at a temperature not in excess of 100° F. Oil-free dry gasoline, dry benzine, or carbon tetrachloride should be used as cleaning solvents. After cleansing, the part should be rinsed carefully with the same oil it is to contain.

OIL SAMPLES - It is often necessary to take samples of oil that has been in use for some time, so that proper dielectric and chemical tests can be made to determine whether the oil is of the proper quality for satisfactory operation. Such tests are frequently the means of preventing breakdown and added expense.

Because the true condition of the oil in use is to be determined, great care should be practiced in drawing off the sample. Precautions regarding contamination by moisture, dirt, or other harmful substances must be carefully observed.

Oil will collect moisture from the fingers, so care must be taken not to permit the hands to come in contact with oil.

Procedure for taking Oil Sample.

The sample may be obtained by the easiest method--pouring, disconnecting a suitable oil line, or syphoning. Whatever method is used, the following procedure should be followed:

Check relative humidity. If below 50%, samples may be obtained.

Operate equipment until the oil temperarure is above that of the room. This will stir up any sludge that may be in the container. In case of a tubehead, it is wise to rotate the head to agitate the oil in order to obtain a true sample.

Clean the area surrounding the point from which the oil is to be removed. Allow the first oil to run to waste.

Clean sample can or bottle of one pint capacity by filling 1/4 full of oil; shake vigorously for at least one minute, and empty. Repeat. Fill to within 1 inch of top and seal tightly.

Tag the sample container showing following data:

1. Humidity at time sample was taken.
2. How humidity value was determined.
3. Officer in charge, x-ray equipment.
4. Type of equipment.
5. Method of obtaining sample.
6. The part of equipment (transformer, tubehead, etc.) sample obtained from.
7. Total number hours operation of oil being tested.

OIL USED - The following types of oil are used in x-ray equipments:

Wemco "C", a pure mineral oil free of moisture, acid, alkali, or free sulphur. It has a slight yellowish tint and is used as an electric insulating oil in contactors (oil type) as well as in transformers and certain types of tubeheads.

Marcol oil is a pure mineral oil free from moisture, acid, alkali, or free sulphur. Has a higher dielectric strength and lower viscosity than Wemco "C" and greater resistance to normal deterioration. It is used as a cooling and insulating medium in shockproof deep therapy installations.

Transil Oil - Use as a dielectric and cooling medium.

When refilling or adding oil to equipment it is necessary to determine first which type of oil is used and be governed accordingly. Most manufacturers use oils very similar to each other. Always use the oil supplied by the manufacturer of the apparatus, if available; in an emergency any good transformer oil supplied by a reliable company may be used. The breakdown test of a good oil is 49 K.V.P. for 0.1 inch between 1 inch discs.

SUMMARY - In conclusion, always use extraordinary precautions in the handling and sampling of transformer oils. Use utmost care in cleansing and rinsing all apparatus used to obtain the oil sample before it is taken. Be certain that the oil is not contaminated and that the right type is used. In this way, failures will be reduced to a minimum.

SECTION XX

X-RAY TUBES

X-RAY TUBES

X-Rays are generated by the impact against a relatively massive target of rapidly moving electrified particles known as electrons. In this series of articles on x-ray physics we will describe the theoretical conditions necessary for x-ray production and the principles of operation of the devices which comprise the x-ray generator, by which means the electrons are produced and accelerated, and through the use of which their number and velocity are controlled to regulate the intensity and nature of the x-ray beam.

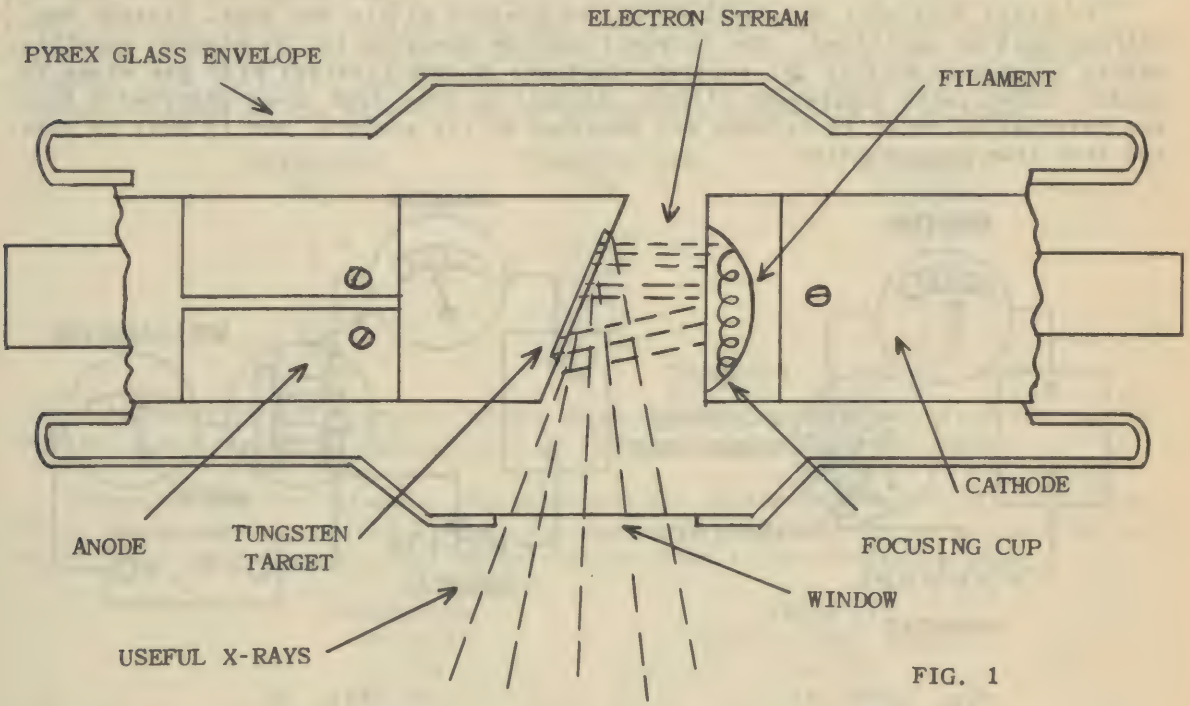


FIG. 1

The above illustration is a sectional drawing on a hot cathode x-ray tube in which the source of electrons is a small coil of tungsten wire which is heated to incandesence by the passage of an electric current through it. The electrons are ejected from the heated wire, the degree of emission being a function of the temperature of the wire and the total area of the surface. Electrons so obtained are designated as thermo-electrons to distinguish them from those which are produced by light action, mechanical friction, or by bombardment of gas atoms. The nature of the electron is the same, however it is produced; it carries a unit negative electrical charge and it has an associated mass which, though quite small, gives the particle a calculable kinetic energy when it is moving at high velocities. It is this kinetic energy, given up in the impact against the target, which is partially converted into the invisible radiation called x-rays. The energy content of the x-ray beam will be dependent on the velocity with which the electrons are moving before impact so that the wave length of the emitted radiation will be an inverse function of the electron speed. The number of such conversions taking place in a given time will depend on the number of electrons striking the target which, as we will see, constitute an electric current flowing through the tube so that the quantity of radiation is proportional to the total number of electrons. The efficiency of conversion of kinetic electron energy to radiation will depend on the rapidity with which the electrons are slowed down in the target and this is related to the density or, more conveniently, the atomic weight of the target material. The energy conversion is a very inefficient one, most of the tube input being lost in the form of

heat which elevates the temperature of the target, the anode, and the adjoining materials, establishing a limit to the current density or energy input fixed by the melting points of the various substances and their temperatures.

Within the framework of electron mechanics, the entire theory of x-ray physics may be established.

In order that only thermo-electrons be present within the tube, certain conditions must be satisfied. The filament must be operated in the highest possible degree of vacuum so that the emitted electrons do not interact with gas atoms to produce undesirable ionization effects, it must be free from gases absorbed within the material of which it is made and absorbed on its surface, and it must be pure and free from contamination.

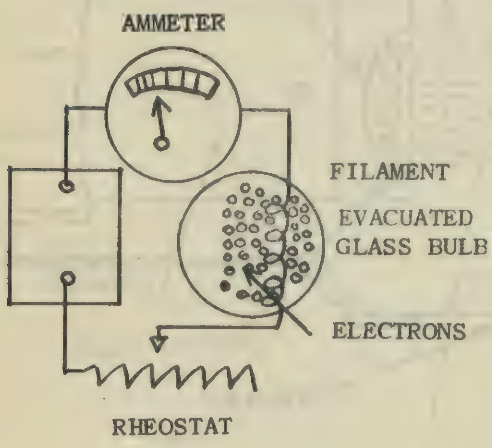


Fig. 2a

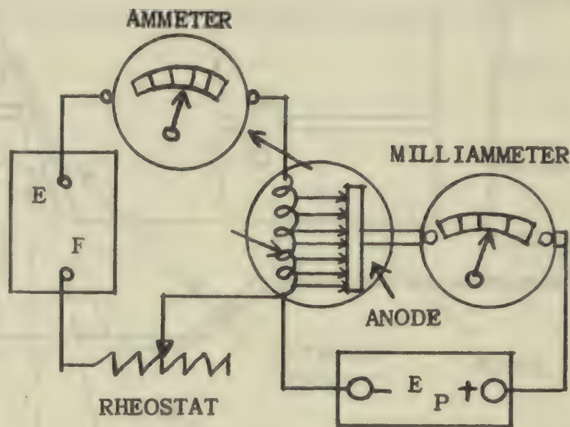


Fig. 2b

In order to control the filament emission, some means must be provided to regulate the current flowing through it, together with an electrical meter for registering the current. In the above illustration, the elementary filament circuit is shown, the source of heating current being symbolically represented by a battery E_F. The means of controlling the filament current is a rheostat, a variable resistance which limits the potential drop across the filament to the difference between the source potential and the drop across itself. The current indicator is the ammeter connected in series with the filament. Under these conditions the heated filament emits electrons with a small velocity of ejection from the wire surface and a cloud of particles, each with a negative charge, is formed to the extent that equilibrium is reached.

Now a collector plate is introduced into the glass bulb and is connected so that its potential is positive with respect to the filament. The negatively charged electrons will then be accelerated in the direction of the positive plate and will constitute an electric current flowing across the vacuum space. The figure to the right illustrates this condition, the plate potential E represented by a battery with its positive terminal connected to the plate and its negative terminal to one side of the filament. These elements can then be called the anode and cathode respectively. The electrons passing from the filament to plate constitute a thermionic current through the vacuum which, because it is a movement of negative charges, is opposite in direction to the conventional current flow from positive potential to negative, the contradiction imposed by the earlier conception of cur-

rents of positive electricity. This need not be confusing if the distinction is kept in mind. The current through the tube is registered on the milliammeter which may be connected at any point in the anode circuit.

In medical diagnostic x-ray practice, the voltage E is sufficiently high, 10,000 to 100,000 volts (peak), to draw practically all available electrons across the tube. The current is then limited by the temperature of the filament, its surface area, and certain constants of the material of which it is composed. The variation of tube current with filament current is a characteristic of great importance. The following table shows emission currents per centimeter length for a tungsten filament of the size ordinarily employed in diagnostic x-ray tubes.

EMISSION MA	TEMPERATURE ^{o}K	FILAMENT CURRENT AMPERES
1.5	2250^{o}	4.0
7	2400^{o}	4.5
35	2550^{o}	5.0
100	2700^{o}	5.5
300	2820^{o}	6.0

From these data it is seen that a change of but one ampere, from 4.5 to 5.5 results in an increase of tube current of fifteen times the initial value.

After leaving the filament, the electrons are accelerated by the electric force due to the potential applied between the anode and cathode. The velocity attained in the field depends on the applied voltage as shown in the following table.

POTENTIAL (volts)	VELOCITY (miles per sec.)
1,000	11,700
10,000	36,500
20,000	50,800
50,000	77,200
100,000	102,000
200,000	130,000
400,000	155,000
1,000,000	175,000

The bombardment of the anode by particles moving at velocities of the order shown above produces two effects:

1. The Generation of heat at the surface of impact.

2. The generation of invisible radiant energy in the form of electromagnetic waves proceeding from the surface of impact and slightly below it.

The minimum wave length of the x-ray spectrum produced by the bombardment is given by the formula:

$$\text{min. wave length} = \frac{12.354}{\text{kv.p.}}$$

For a tube-voltage of 120 kv.p. the wave length limit is approximately 0.1 Angstrom unit or 10^{-9} centimeters.

THE X-RAY TUBE - In the design of a vacuum tube specifically for x-ray production, the following requirements may be concluded from the theory thus far outlined:

1. The source of electrons must be a material capable of withstanding high filament temperatures since the emission is a function of temperature. Tungsten, with a melting point of 3370° C., is well suited.

2. The target must also be capable of operating at elevated temperature since practically the entire electrical input to the tube is dissipated in the form of heat generated in the area of electron impact.

3. The target should be a material of high atomic number, since the efficiency of x-ray production is proportional to this figure. Tungsten, atomic number 74, satisfies this requirement.

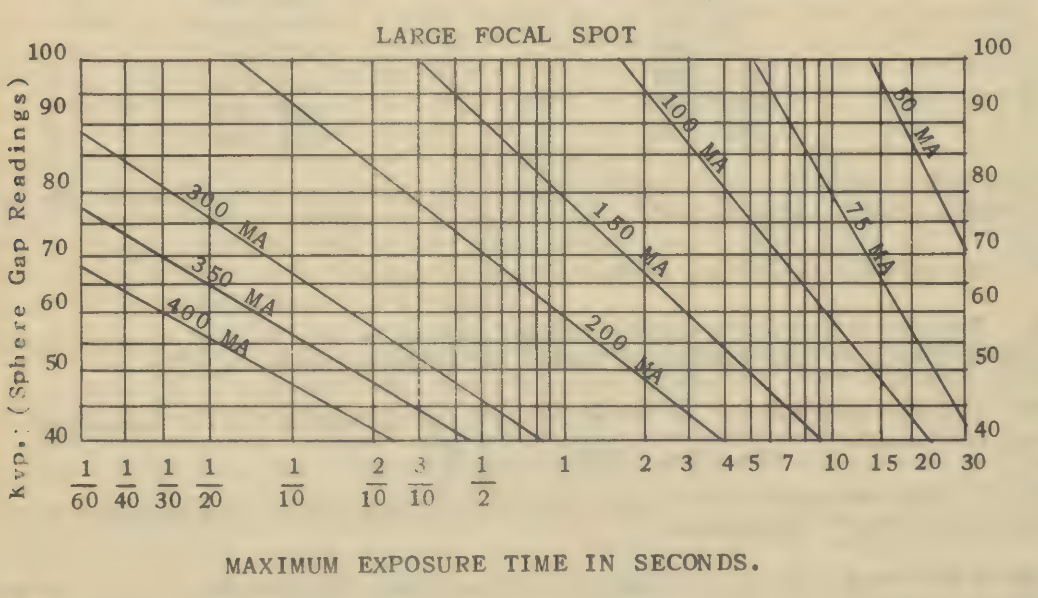
4. The tube must be operable at high voltages in order that sufficiently large velocities be imparted to the electrons. In medical diagnostic radiography, the upper limit is about 100 ky.p.

5. In order that the current through the tube be a pure electron discharge, all gases must be pumped out of the space within the bulb, the anode and cathode must be thoroughly out-gassed by special exhaust procedures, and the glass itself must be freed from occluded gases.

The principal factors determining the rating of the x-ray tube are, first, the limitation due to temperature of the focal area and, second, the limitation due to the thermal capacity of the anode and casing and the effectiveness of the latter in dissipating heat to the surrounding air.

For short times of exposure, one second or less, the tube rating is based mainly on the focal spot melting energy, for longer times the entire anode becomes effective as a cooling medium, and energy transferred to it by conduction may raise its temperature to the limiting value.

Limits of safe operation are given in the form of tube rating charts for each type of tube and for the various focal spot sizes manufactured in a particular type.



MAXIMUM EXPOSURE TIME IN SECONDS.

One of these is shown in the preceding figure for a focal area 4.5 mm., measured in projection at right angles to the tube axis in accordance with the conventional expression of focal area. The three factors given by the curves are:

1. Time of exposure (sec.)
2. Tube voltage (kv.p.)
3. Tube current (ma.)

With any two of these known, the third is found at the point of their intersection. For example, the maximum current at 70 kv.p. and 1/10 second is 270 ma. the tube voltage limit at 200 ma. and 1/10 second is 94 kv.p.; the maximum time of exposure at 100 ma. and 100 kv.p. is 1-3/4 second.

The rating chart only partially specifies the operating characteristics of an x-ray tube since it indicates the limitation for a single exposure, but gives no information as to the rapidity with which exposures can be made. Safe limits must be specified for the total energy input and the time of cooling necessary after the limit is reached.

Space limitation prevents an inclusion of further discussion of this important problem, but specific data can be obtained from x-ray tube manufacturers for all types.

The essential requirements for the operation of an x-ray tube are:

1. A source of filament heating potential.
2. A device for controlling the filament current.
3. A meter for indicating the filament current.
4. A source of anode potential for accelerating the electrons.
5. A device for controlling the anode potential.
6. A meter for indicating the x-ray tube current.

X-RAY TUBE CONSTRUCTION

GENERAL - Fundamentally, an x-ray tube consists of obtaining a stream of electrons moving with very high velocity and stopping these electrons suddenly by having them strike a solid body. An x-ray tube is very inefficient as less than 1% of the energy applied is emanated as x-rays, the remainder being dissipated in heat.

THE EVACUATED ENVELOPE - The evacuated envelope, or bulb, serves as a means of surrounding the other parts of the tube with a vacuum and also supports the two electrodes (cathode and anode) and insulates them from each other. Glass is used as envelope material for it has a high dielectric strength, low x-ray absorption and can be fabricated easily. The inside of the glass bulb receives a negative charge of stray electrons. Thus, there is a difference of potential between the inner and outer surfaces of the glass, depending on the voltage at which the tube is operated; and the glass must have sufficient thickness to withstand this potential. On the other hand, if the glass is too thick it will absorb x-rays of long wave lengths produced by low-kilovoltages. In some tubes the envelope is ground down or a window is inserted at the point where the beam of x-rays emerges to reduce the absorption.

ANODE AND FOCAL SPOT DESIGN - During operation only about one-tenth of one percent of the input energy is converted into x-rays, the remainder of the energy is transformed into heat. It is the function of the anode to absorb and dissipate heat, and the rate of dissipation determines the capacity of the tube.

Tungsten is used for target material because of its high efficiency in the production of x-rays, high melting point, good heat conductivity, low vapor pressure at high temperature and mechanical strength. The melting point of tungsten is 3300° C. The vapor pressure of tungsten is only 1/1000 mm of mercury at 2700° C. For this reason, it is a good target material for any metallic vapors liberated would disturb the stability of an x-ray tube.

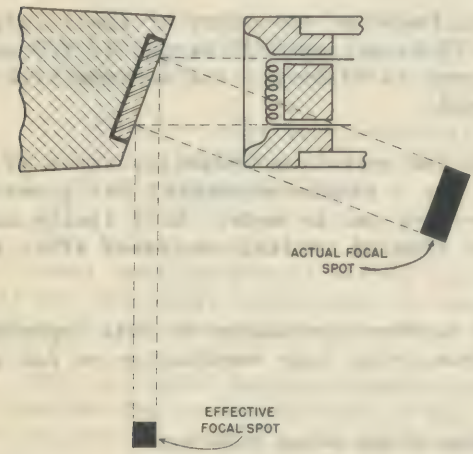


Diagram of line-focus tube depicting relation between actual focal spot (area of bombardment) and effective focal spot, as projected from 20° anode.

A focal spot is but one of the factors influencing radiographic film detail. Power required, time and distance from tube to part, the focal spot shape, size and angular position with respect to the film are also of great importance. Most modern x-ray tubes are of the line or band focus types. This type has the focal spot in the form of a rectangle with the target face placed at an angle of 15° - 20° to the axis of the tube, while in the old type the target was at an angle of 45° to the cathode. The result in the line focus tube is that the normal projection of the target on the film, or tne effective focal spot, is in the form of a small square about 1/3 the size of the target area. Therefore, for a given effective focal spot size, the capacity of the tube is greatly increased. This is illustrated in the diagram.

AEROMAX "8" SERIES OF X-RAY TUBES SHOCKPROOF DIAGNOSTIC TYPE

The Aeromax "8" shockproof x-ray tubes are of the stationary anode diagnostic type, specially designed to provide high heat storage capacity and rate of heat dissipation for radiographic service and fluoroscopy.

INSERT TUBES - Heavy anode Pyrex glass tubes with 20° linear focal spots. available in single and double focus models with choice of a variety of focal sizes and combinations as listed below.

HOUSING - Constructed of sheet steel and lined with lead. Filled with specially processed insulating oil under vacuum and heremtically sealed. Provided with expansion chambers adequate to take care of oil expansion through full range of operating temperatures. Shockproof and rayproof to the extent required by the International Recommendations for X-Ray Protection.

CABLES - Energy is supplied through insulated and shielded cables removably connected to the housing by a vapor-proof plug-and-socket arrangement. These cables have been specially developed for high insulation strength, and for great flexibility and ease of manipulation. Terminals at the remote end may be, alternatively as specified on order, of a type for connection to an overhead aerial circuit, or of a type for connection direct to the transformer by a plug-and-socket arrangement. Ceiling supports for the cables, if required, for use with the former type of terminals, and sockets for mounting in transformer housings, for use with the latter, are available. Terminals for other special arrangements will be furnished,

if practicable, upon request accompanied by proper instructions.

WEIGHT - To be counterbalanced, with cables in place, 21 pounds.

RATINGS

MAXIMUM VOLTAGE - 100 PKV (voltage to ground not to exceed 50 PKV).

MAXIMUM ENERGY - For radiography, in accordance with individual charts for each focal spot size (see diagrams that follow).

For fluoroscopy, 85 PKV, 5 MA, 15 minutes, starting with tube cold.

THERMAL CHARACTERISTICS - Total heat storage capacity--300,000 units.
Maximum cooling rate--8,000 units per minute.
Cooling chart appears hereafter.

AEROMAX "8"

RATING CHARTS - The charts below indicate the energy ratings in terms of the usual radiographic exposure factors of peak kilovolts, milliamperes, and seconds, throughout the range of exposures commonly employed in radiography. Note that a separate set of charts is given for each of the focal spot sizes included in the Aeromax "8" series. The letter indicating the focal spot size of each individual tube is stamped on the name plate thereof. Note also that each set of charts includes a separate chart for each of three different conditions of operation, namely, full-wave rectification, half-wave rectification, and self-rectification. For other conditions of operation, such as three-phase or condenser discharge, apply to the Machlett Engineering Department for rating information.

The rating charts serve as a guide in selecting the proper focal spot size for any given set of technique factors, or for setting up technique factors for use with any given focal spot size. In order to obtain satisfactory tube life, the focal size should be such that the tube ratings are not exceeded by the maximum energy

required for the techniques to be used. In order to obtain the best radiographic results, the focal size should be no larger than that required to permit the use of such energies.

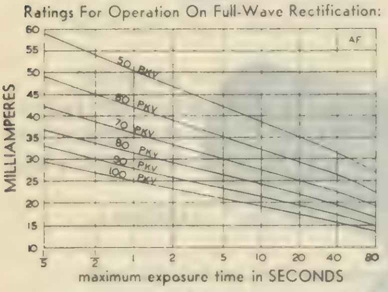
A minimum of five seconds must be allowed between exposures when maximum values are used. For stereo pairs, where exposures are made in rapid succession, each exposure should be limited to two-thirds of the time values given by the charts.

Interpretation of the charts consists of determining the limiting value of the third factor when the other two factors are known or assumed. For example, on the chart for "B" focus, full-wave rectification, it will be noted that if a PKV value of 90 and MA of 60 are assumed, the limiting time factor can be determined by locating the point of intersection of the curved line corresponding to 90 PKV and the horizontal line corresponding to 60 MA, and reading the value of this point on the time scale, which gives approximately one second. ∴ converse prodedure indicates that the limiting value of PKV for a one second exposure at 60 MA is 90. In other words, it is safe to use for such an exposure any value of PKV below 90, but not in excess of 90.

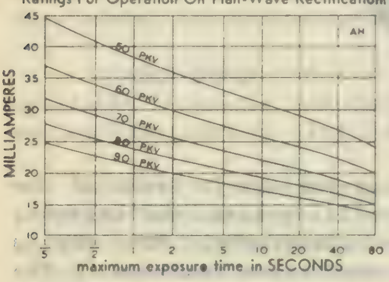
"A" FOCAL SPOT

Effective Size — 1.5 m.m.
Filament Characteristics — 3.5 to 4.5 Amps 3.0 to 4.0 Volts

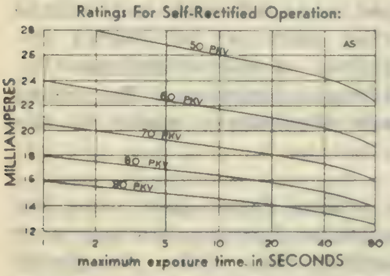
Ratings For Operation On Full-Wave Rectification:



Ratings For Operation On Half-Wave Rectification:



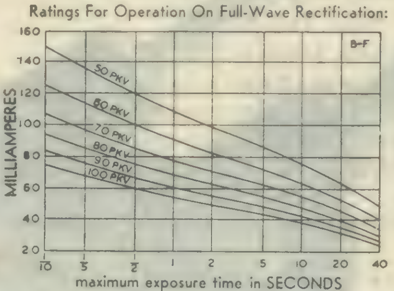
Ratings For Self-Rectified Operation:



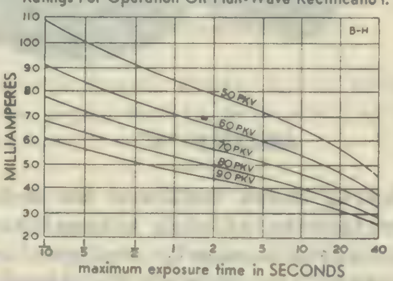
"B" FOCAL SPOT

Effective Size — 2.3 m.m.
Filament Characteristics — 3.7 to 4.7 Amps 3.5 to 5.0 Volts

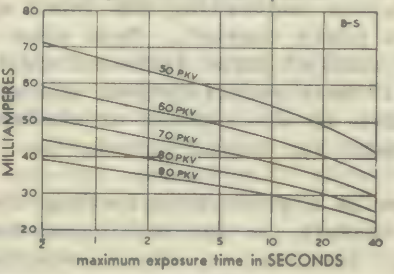
Ratings For Operation On Full-Wave Rectification:



Ratings For Operation On Half-Wave Rectification:



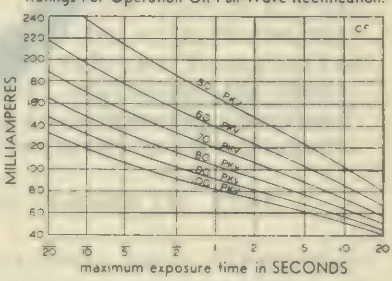
Ratings For Self-Rectified Operation:



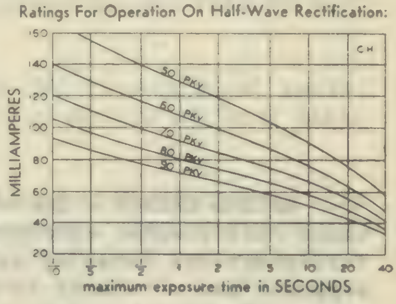
"C" FOCAL SPOT

Effective Size — 3.2 m.m.
Filament Characteristics — 4.0 to 5.0 Amps 5.0 to 7.0 Volts

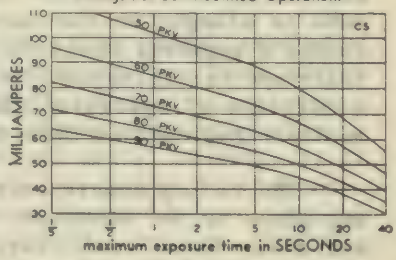
Ratings For Operation On Full-Wave Rectification:



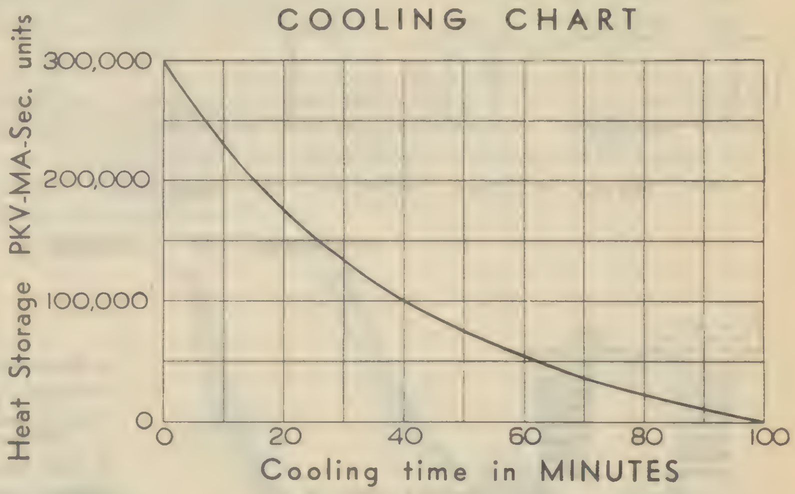
Ratings For Operation On Half-Wave Rectification:



Ratings For Self-Rectified Operation.

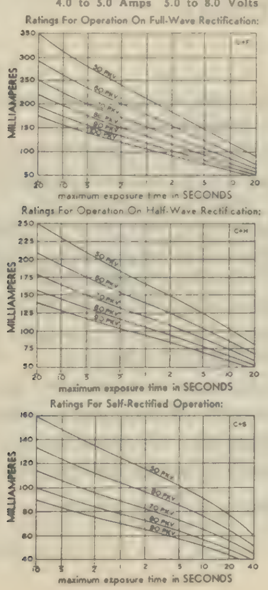


COOLING CHART - The heat generated by each exposure is stored within the tube head and dissipated gradually in accordance with the chart below. Heat is defined in terms of units represented by the product of PKV x MA x Seconds on a single-phase generator. (With a 3-phase generator, this product must be multiplied by 1.35 to obtain the correct number of units.) The maximum heat storage capacity of the Aeromax "8" unit is 300,000 units, and at this value of stored heat, the cooling rate, as indicated by the chart, is 8,000 units per minute. The rate at which heat dissipation takes place at the other values of stored heat may be determined from the curve.

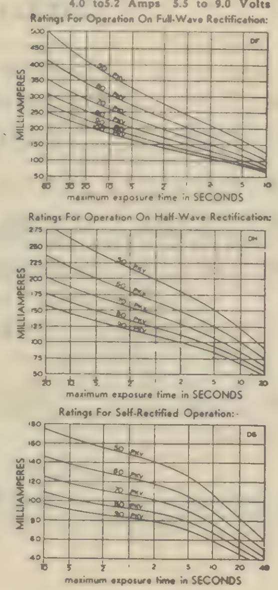


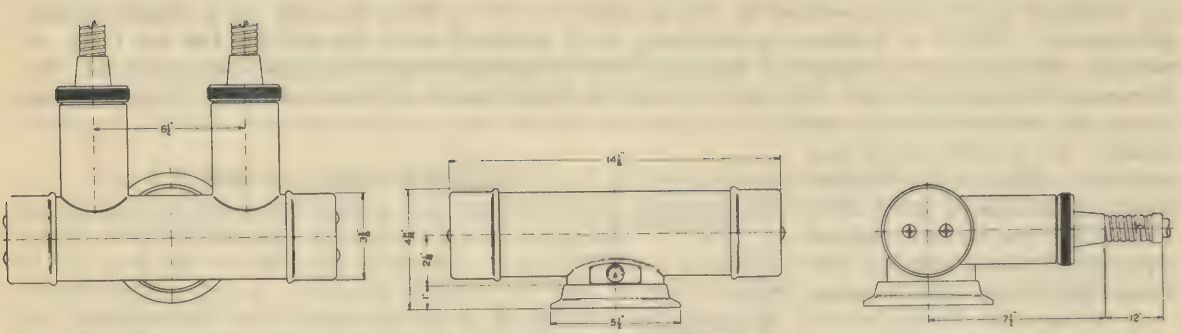
If a series of exposures to be made in succession involve a greater number of heat units than the maximum storage capacity value of 300,000, then consideration must be given to the cooling rate. For example, suppose chest photoroentenograms are to be made at 200 MA, 2 second, 90 PKV at a rate of 4 per minute for several hours. This procedure would involve 14,400 units per minute, and at the end of 21 minutes would involve a total heat value in excess of 300,000 units. The tube can dissipate 8,000 units per minute, and hence the rate of input must be reduced to that value to avoid over-heating. This rate would permit two such exposures every minute.

"C PLUS" FOCAL SPOT
Effective Size — 3.8 m.m.
Filament Characteristics —
4.0 to 5.0 Amps 5.0 to 8.0 Volts



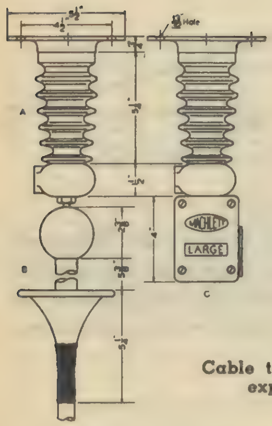
"D" FOCAL SPOT
Effective Size — 4.2 m.m.
Filament Characteristics —
4.0 to5.2 Amps 5.5 to 9.0 Volts





TOP VIEW FRONT VIEW END VIEW

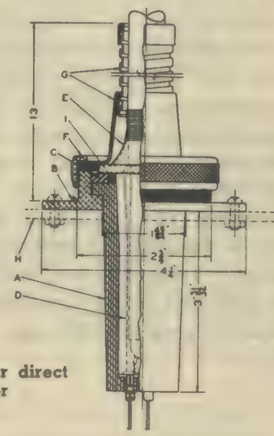
DIMENSIONAL DATA — AEROMAX "8"



A—Ceiling support for cable
B—Cable Terminal
C—Cord operated ceiling switch for double-focus tubes

Cable terminal arrangement for exposed aerial system

A—Socket Insulator
B—Mounting Flange
C—Socket Insulator Holding Nut
D—Cable Insulator
E—Cable Grounding Flare
F—Cable Nut
G—Cable Guard
H—Transformer Top
I—Vapor-proofing Gasket



Cable terminal arrangement for direct connection to transformer

CATALOG LISTINGS:

Focal Size	Designation	Cat. No.
1.5 mm.	AEROMAX "8"-A	C-471A
2.3 mm.	AEROMAX "8"-B	C-472A
3.2 mm.	AEROMAX "8"-C	C-473A
3.8 mm.	AEROMAX "8"-C plus	C-469A
4.2 mm.	AEROMAX "8"-D	C-474A
1.5 mm.) 3.8 mm.)	AEROMAX "8"-AC plus	C-476A
2.3 mm.) 4.2 mm.)	AEROMAX "8"-BD	C-477A

AEROMAX Cables:

	Cat. No.
Eight-foot, double-focus cathode	C-384*
Eight-foot, single-focus anode or cathode, or double-focus anode	C-385*
Twelve-foot, double-focus cathode	C-386*
Twelve-foot, single-focus anode or cathode, or double-focus anode	C-387*
Sixteen-foot, double-focus cathode	C-388*
Sixteen-foot, single-focus anode or cathode, or double-focus anode	C-389*
Ceiling supports for AEROMAX cables	C-350
Ceiling Switch for use with double-focus AEROMAX tubes	C-360
Transformer receptacles for plug-in connection of single-focus Aeromax cables	C-411
Transformer receptacles for plug-in connection of double-focus Aeromax cables	C-412

* Specify if cables are for use with transformer receptacles.

AEROMAX "12" SERIES OF X-RAY TUBES SHOCKPROOF DIAGNOSTIC TYPE

The Aeromax "12" shockproof x-ray tubes are of the stationary anode diagnostic type, specially designed to provide unusually high heat storage capacity and rate of heat dissipation for extremely heavy duty radiographic service, for fluoroscopy, and for superficial therapy. An Air-Circulator is provided as an optional attachment to still further increase the rate of heat dissipation if desired.

INSERT TUBES - Heavy anode Pyrex glass tubes with 20° linear focal spots. Available in single and double focus models with choice of a variety of focal sizes and combinations as listed below. Specially processed for operation at high continuous energy levels.

HOUSING - Constructed of sheet steel and lined with lead. Filled with specially processed insulating oil under vacuum and hermetically sealed. Provided with expansion chambers adequate to take care of oil expansion through full range of operating temperatures. Shockproof and rayproof to the extent required by the International Recommendation for X-Ray Protection.

AEROMAX "12" with Air-Circulator

AEROMAX "12" without Air-Circulator

CABLES - Energy is supplied through insulated and shielded cables removably connected to the housing by a vapor-proof plug-and-socket arrangement. These cables have been specially developed for high insulation strength, and for great flexibility and ease of manipulation. Terminals at the remote end may be, alternatively as specified on order, of a type for connection to an overhead aerial circuit or of a type for connection direct to the transformer by a plug-and-socket arrangement. Ceiling supports for the cables, if required, for use with the former type of terminals, and sockets for mounting in transformer housings, for use with the latter, are available. Terminals for other special arrangements will be furnished, if practicable, upon request accompanied by proper instruction.

AIR-CIRCULATOR - Use of Air-Circulator is optional. When required, it is attached by removing handle regularly supplied with the Aeromax "12" head, and attaching the circulator in place thereof. Operation of its motor requires connection to a 110 volt a.c. circuit, which should be wired so as to be turned on continuously whenever the X-Ray machine is being used.

WEIGHT - To be counterbalanced, with cables in place: 21 pounds without Air-Circulator; 24 pounds with Air-Circulator.

X-RAY TUBES

RATINGS

MAXIMUM VOLTAGE - 110 PKV, full wave rectified; 100 PKV, half-wave or self-rectified (maximum inverse voltage not to exceed 50 PKV to ground).

MAXIMUM ENERGY - For radiography, in accordance with individual charts for each focal spot size (see diagrams that follow). Additional rating for B focal spot and larger on full-wave rectification, 110 PKV, 20 MA, 1 minute.

For fluoroscopy or therapy, per the following schedule:

Without Air-Circulator--85 PKV, 5 MA or 100 PKV, 4 MA for 30 minutes continuously, starting with tube cold; equal on and off periods of 10 minutes maximum thereafter.

With Air-Circulator--85 PKV, 5 MA or 100 PKV, 4 MA continuous indefinitely.

THERMAL CHARACTERISTICS - Total heat storage capacity--500,000 units. Maximum cooling rate--12,500 units per minute, without Air-Circulator, 25,000 units per minute, with Air-Circulator.

Cooling Chart appears hereafter.

RATING CHARTS - The charts below indicate the energy ratings in terms of the usual radiographic exposure factors of peak kilovolts, milliamperes, and seconds, throughout the range of exposures commonly employed in radiography. Note that a separate set of charts is given for each of the focal spot sizes included in the Aeromax "12" series. The letter indicating the focal spot size of each individual tube is stamped on the name plate thereof. Note also that each set of charts includes a separate chart for each of three different conditions of operation, namely, full-wave rectification, half-wave rectification, and self-rectification. For other conditions of operation, such as three-phase or condenser discharge, apply to the Machlett Engineering Department for rating information.

The rating charts serve as a guide in selecting the proper focal spot size for any given set of technique factors, or for setting up technique factors for use with any given focal spot size. In order to obtain satisfactory tube life, the focal size should be such that the tube ratings are not exceeded by the maximum energy required for the techniques to be used. In order to obtain the best radiographic results, the focal size should be no larger than that required to permit the use of such energies.

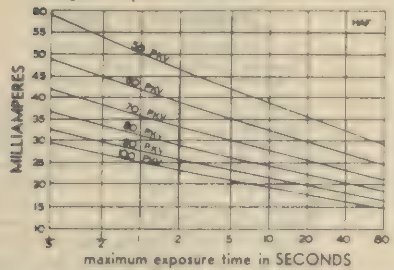
A minimum of five seconds must be allowed between exposures when maximum values are used. For stereo pairs, where exposures are made in rapid succession, each exposure should be limited to two-thirds of the time values given by the charts.

Interpretation of the charts consists of determining the limiting value of the third factor when the other two factors are known or assumed. For example, on the chart for "B" focus, full-wave rectification, it will be noted that if a PKV value of 90 and MA of 60 are assumed, the limiting time factor can be determined by locating the point of intersection of the curved line corresponding to 90 PKV and the horizontal line corresponding to 60 MA, and reading the value of this point on the time scale, which gives approximately one second. A converse procedure indicates that the limiting value of PKV for a one second exposure at 60 MA is 90. In other words, it is safe to use for such an exposure any value of PKV below 90, but not in excess of 90.

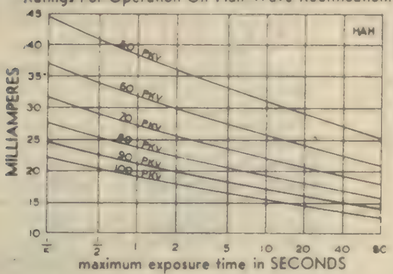
"A" FOCAL SPOT

Effective Size — 1.5 m.m.
Filament Characteristics —
3.5 to 4.5 Amps., 3.0 to 4.0 Volts

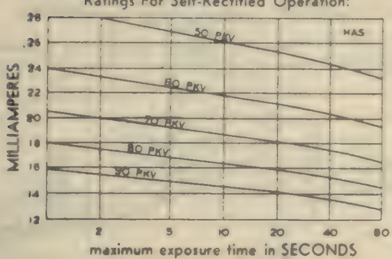
Ratings For Operation On Full-Wave Rectification:



Ratings For Operation On Half-Wave Rectification:



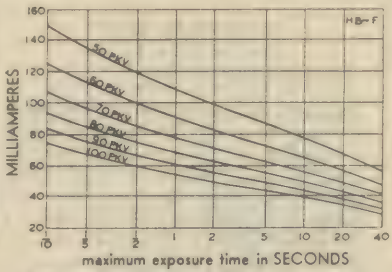
Ratings For Self-Rectified Operation:



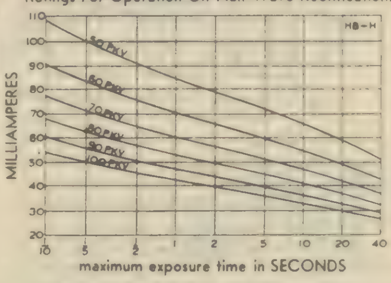
"B" FOCAL SPOT

Effective Size — 2.3 m.m.
Filament Characteristics —
3.7 to 4.7 Amps., 3.5 to 5.0 Volts

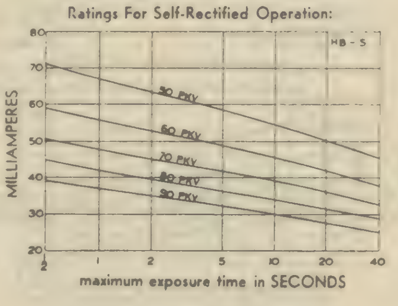
Ratings For Operation On Full-Wave Rectification:



Ratings For Operation On Half-Wave Rectification:



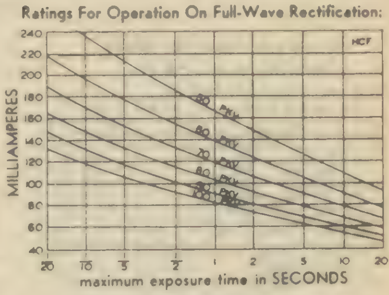
Ratings For Self-Rectified Operation:



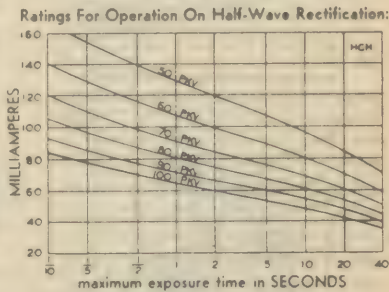
"C" FOCAL SPOT

Effective Size — 3.2 m.m.
Filament Characteristics —
4.0 to 5.0 Amps. 5.0 to 7.0 Volts

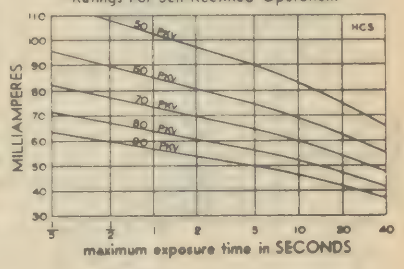
Ratings For Operation On Full-Wave Rectification:



Ratings For Operation On Half-Wave Rectification:



Ratings For Self-Rectified Operation:



COOLING CHART - The heat generated by each exposure is stored within the tube head and dissipated gradually in accordance with the chart that follows. Heat is defined in terms of units represented by the product of PKV x MA x Seconds on a single-phase generator. (With a 3-phase generator, this product must be multiplied by 1.35 to obtain the correct number of units.) The maximum heat storage capacity of the Aeromax "12" unit is 500,000 units, and at this value of stored heat, the cooling rate, as indicated by the chart, is 12,500 units per minute without the air-circulator and 25,000 units per minute with it. The rate at which heat dissipation takes place at other values of stored heat may be determined from the curve.

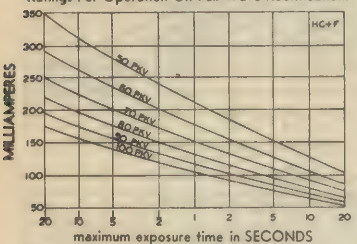
If a series of exposures to be made in succession involve a greater number of heat units than the maximum storage capacity value of 500,000, then consideration must be given to the cooling rate. For example, suppose chest photoroentenograms are to be made at 200 MA, .2 second, 90 PKV at a rate of 4 per minute for several hours. This procedure would involve 14,400 units per minute, and at the end of 35 minutes would involve a total heat value in excess of 500,000 units. With the air-circulator the tube can dissipate 25,000 units per minute, and hence the maximum heat storage capacity could not be exceeded under these conditions. However, without the air-circulator, the maximum cooling rate is 12,500 units per minute, and after

the stored heat has attained the 500,000 unit value, the rate of input must be reduced to 12,500 units per minute to avoid over-heating. This rate would permit four such exposures every 70 seconds instead of every 60 seconds.

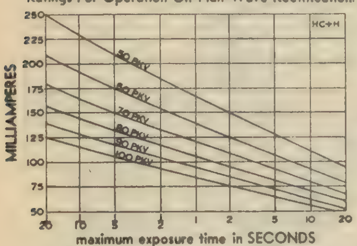
"C PLUS" FOCAL SPOT

Effective Size — 3.8 m.m.
Filament Characteristics —
4.0 to 5.0 Amps., 5.0 to 8.0 Volts

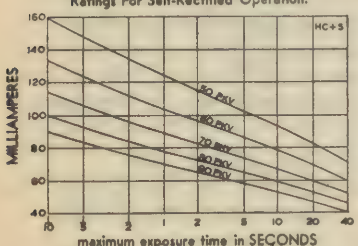
Ratings For Operation On Full-Wave Rectification:



Ratings For Operation On Half-Wave Rectification:



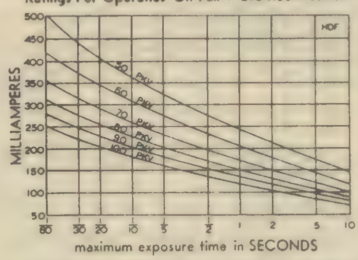
Ratings For Self-Rectified Operation:



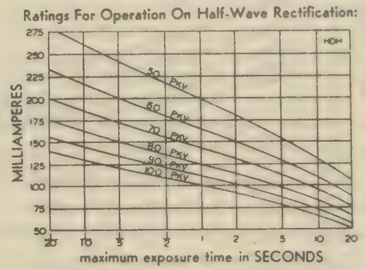
"D" FOCAL SPOT

Effective Size — 4.2 m.m.
Filament Characteristics —
4.0 to 5.2 Amps., 5.5 to 9.0 Volts

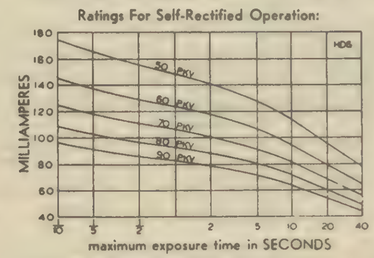
Ratings For Operation On Full-Wave Rectification:



Ratings For Operation On Half-Wave Rectification:



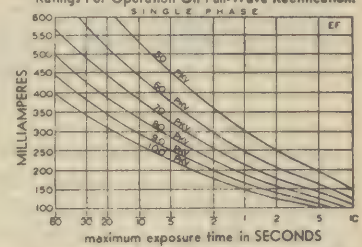
Ratings For Self-Rectified Operation:



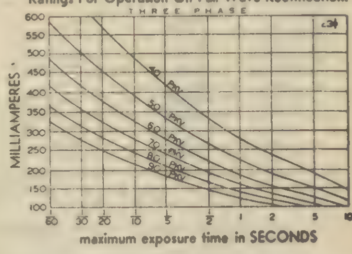
"E" FOCAL SPOT

Effective Size — 5.0 m.m.
Filament Characteristics —
4.0 to 5.5 Amps., 5.5 to 10.0 Volts

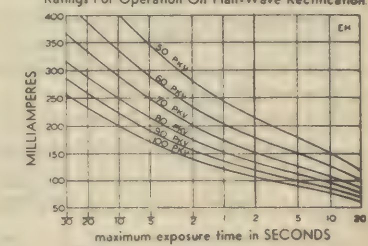
Ratings For Operation On Full-Wave Rectification:



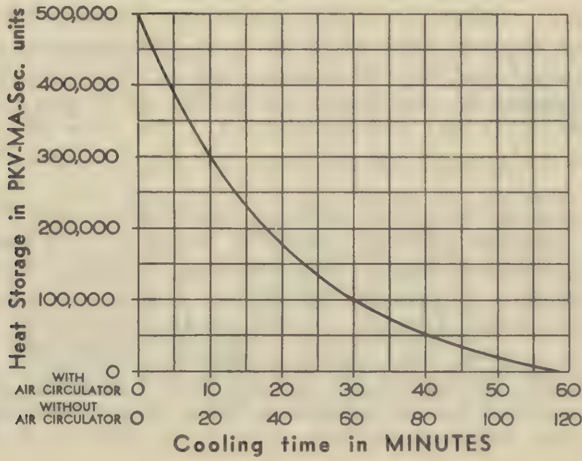
Ratings For Operation On Full-Wave Rectification:

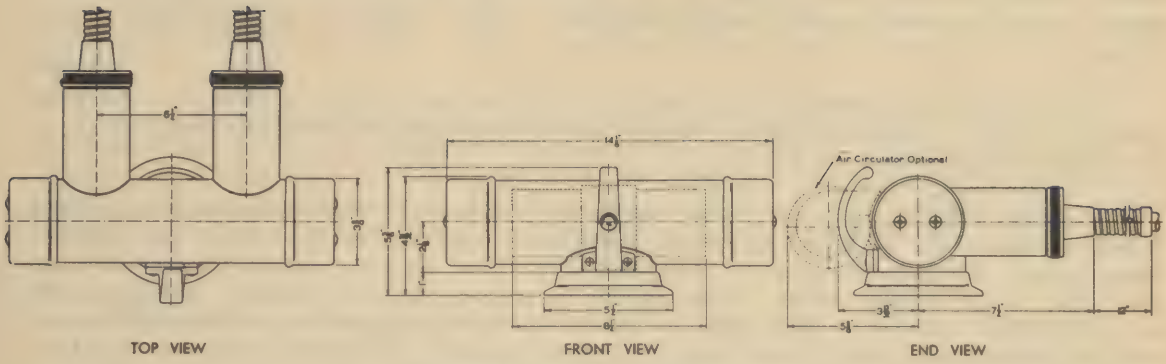


Ratings For Operation On Half-Wave Rectification

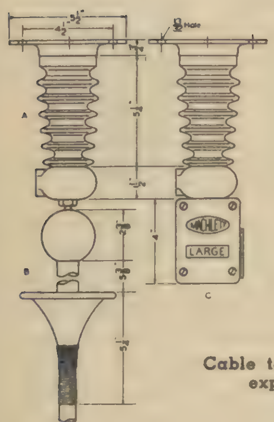


COOLING CHART





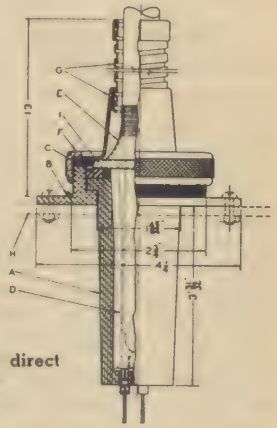
DIMENSIONAL DATA — AEROMAX "12"



A—Ceiling support for cable
B—Cable Terminal
C—Cord operated ceiling switch for double-focus tubes

Cable terminal arrangement for exposed aerial system

A—Socket Insulator
B—Mounting Flange
C—Socket Insulator Holding Nut
D—Cable Insulator
E—Cable Grounding Flare
F—Cable Nut
G—Cable Guard
H—Transformer Top
I—Vapor-proofing Gasket



Cable terminal arrangement for direct connection to transformer

CATALOG LISTINGS:

Focal Size	Designation	Cat No.
1.5 mm.	AEROMAX "12"-A	C-491A
2.3 mm.	AEROMAX "12"-B	C-492A
3.2 mm.	AEROMAX "12"-C	C-493A
3.8 mm.	AEROMAX "12"-C plus	C-495A
4.2 mm.	AEROMAX "12"-D	C-494A
1.5 mm.) 3.8 mm.)	AEROMAX "12"-AC plus	C-496A
2.3 mm.) 4.2 mm.)	AEROMAX "12"-BD	C-497A
2.3 mm.) 5.0 mm.)	AEROMAX "12"-BE	C-490A
Air-Circulator for use with AEROMAX "12"		C-498

AEROMAX Cables:	Cat No.
Eight-foot, double-focus cathode	C-384*
Eight-foot, single-focus anode or cathode, or double-focus anode	C-385*
Twelve-foot, double-focus cathode	C-386*
Twelve-foot, single-focus anode or cathode, or double-focus anode	C-387*
Sixteen-foot, double-focus cathode	C-388*
Sixteen-foot, single-focus anode or cathode, or double-focus anode	C-389*
Ceiling supports for AEROMAX cables	C-350
Ceiling Switch for use with double-focus AEROMAX tubes	C-360
Transformer receptacles for plug-in connection of single-focus Aeromax cables	C-411
Transformer receptacles for plug-in connection of double-focus Aeromax cables	C-412

* Specify if cables are for use with transformer receptacles

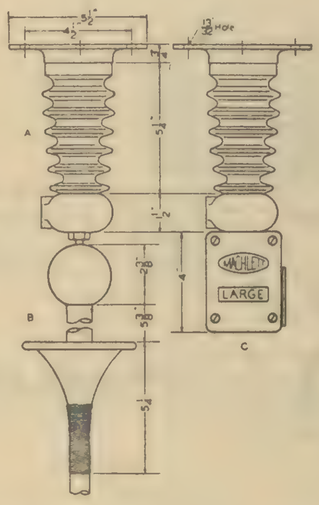
AEROMAX "8" - AEROMAX "12"

INSTALLATION - Mount the tube on the tube-stand by means of the conical adapter supplied with the tube, which is attached to the tube carriage in the same manner as the conventional lead glass bowl, or by means of any other mounting arrangement that may be supplied in special cases.

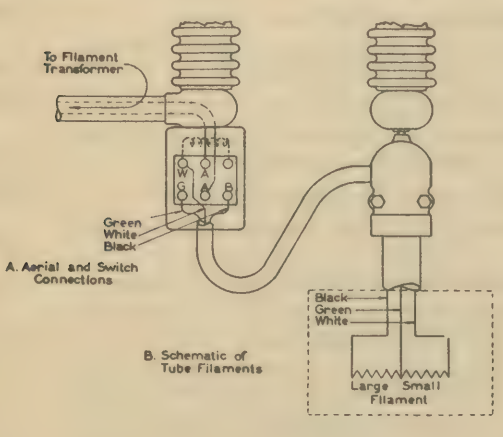
Ground the Tube-Head positively by a firm electrical connection to some grounded object. (Ordinarily the tube-stand is grounded, and the tube housing is in electrical contact therewith.)

Connect Cables to tube. The removable cables are equipped with plug type terminals which fit into corresponding sockets mounted in the tube unit. For double-focus tubes, the cathode cable is equipped with three contact prongs, the anode with two. For single-focus tubes, both cables have two contact prongs, the anode and cathode cables being interchangeable. Each terminal plug should be heavily coated with petroleum jelly and fitted with a neoprene gasket, which materials are supplied with the cables, before inserting in the socket, thus making the terminals vapor-proof. The terminals are held in place by large knurled nuts, which should be screwed firmly in place at time of installation.

Connect cables to high-tension supply. Unless otherwise specified, the cables are furnished equipped with fittings for connection to the conventional type of overhead high-tension system. Ceiling insulators are supplied, if specially ordered, for suspending the cable terminals as indicated at right. Otherwise the terminals may be attached to the aerial system direct. When ceiling switch is used with double-focus tubes for focus selection, filament circuit connections are made as indicated below. When ceiling switch is not used but two filament transformers or some other means of focus selection are employed, the proper filament connections can be determined from the figure below. Cables for single-focus tubes have only two leads developed for connecting to the filament supply.



Cable Terminal Arrangement for Exposed Aerial System.



Double-Focus Filament Circuit Connections for Ceiling Switch.

Receptacles for mounting in the transformer tank, and cables with terminals arranged for plugging into these receptacles, are supplied when so ordered. The manner of mounting the receptacles in the transformer tank is illustrated in the figure that follows. For a double-focus tube, the socket insulator for the cathode side is provided with three terminal prongs, and the proper connections for the large and small focus respectively are indicated in the figure that follows.

Special cable terminal arrangements to fit transformer sockets as designed by

various equipment manufacturers will require special connections in accordance with instructions furnished with such equipment.

Check counterweighting of tube-stand with cables in place, and adjust if necessary.

Connect Air-Circulator to power supply if tube is equipped with Air-Circulator (Aeromax "12" may be so equipped if desired). A 105-125 volt 50-60 cycle supply is required. It should be so connected that the circulator will be turned on with the main switch supplying the X-ray installation so that it will operate continuously between exposures although the machine itself is turned off to conserve the tube and valve filaments.

OPERATION - Calibrate the equipment after the tube has been installed.

Milliamperage calibration is necessary to permit the filament current to be properly preset for the desired milliamperage before each exposure. If a CALIBRATION CHART is used for this purpose. the chart must be checked, and revised if necessary, whenever a new tube is installed. If the machine has semi-automatic filament control or is of the fixed-milliamperage type, the settings of the control circuit must be readjusted to compensate for any variation in filament characteristics. Make no filament current settings in excess of 5.5 amps.

Kilovoltage calibration should be checked to make sure that maximum voltage ratings of the tube will not be exceeded. If the tube is of a different type from that previously used, recalibration for voltage is essential. Different tube characteristics and cable capacitance may result in entirely different peak voltage values for given primary settings. The kilovoltage measurements must be made with an accurately calibrated sphere gap, or some other type of peak voltmeter. (If the transformer unit is of the shockproof type with no exposed terminals, the gap may be connected at the tube end of the cables by means of a special adapter for the purpose. Information on such an adapter is available from the Machlett Engineering Department.) For purposes of checking against voltage rating, maximum peak voltages, whether inverse or surge, must be determined, as these are the values which stress the cables and other insulation. If the unit is of the single-valve rectified type, the voltage to ground on the side not including the valve must be measured, and this value must not be allowed to exceed one-half the maximum voltage rating of the tube for unrectified voltage.

For maximum voltage ratings, refer to the specification sheet pertaining to the particular type of tube involved.

With single-valve generators, the insertion of a 10,000 ohm resistor (200-watt wire wound type) in series with the transformer on the unrectified side is usually found helpful in suppressing high-frequency surges set up in the cables by the distorted wave-form. With mechanically rectified generators, such a resistor on each side of the circuit may be helpful. Rephasing of the rectifier discs may also be necessary.

CAUTION - During all calibration procedures, take care not to exceed the maximum energy, maximum voltage, and heat storage ratings of the tube.

Radiographic operation may be in accordance with any approved technique which does not exceed the tube's ratings. Time ratings for various values of MA and PKV are given by the rating charts accompanying the tube. Make sure that the chart corresponds to the tube with reference to focal spot size, and that the correct

portion of the chart with reference to type of rectification is used. Check the technique chart for any condition which may exceed the ratings.

Heat storage and dissipation characteristics must be considered when making *numerous exposures* in rapid succession. These characteristics are given in the specification sheet for each type of tube. The total heat of any series of exposures must not exceed the heat storage capacity of the tube unless sufficient cooling periods are allowed to dissipate the excess. Check any proposed schedule of exposures against the thermal characteristics of the tube to make sure these conditions are complied with. Make sure that the chart referred to corresponds with the particular type of tube involved.

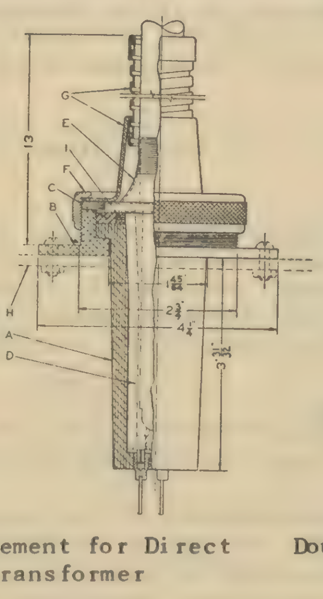
For fluoroscopy or therapy, do not exceed the time and energy limitations indicated in the specifications of the tube. When the full heat storage capacity of the tube has been utilized by one or a series of exposures, proper cooling time must be allowed before starting additional exposures. When an Air-Circulator is employed with the tube, make sure that it is operating properly, and that it continues to operate during all cooling intervals allowed in accordance with the cooling chart.

MAINTENANCE - Tube replacement. The X-ray tube itself is mounted and sealed in the tube unit. This process is carried out in the factory to insure the conditions for proper operation. When tube failure occurs, a factory-processed replacement tube unit should be secured. The unit containing the unserviceable tube is to be returned to the factory or service depot. The original packing should be employed in making the return. The Service Report form supplied with the tube should be filled out and also returned.

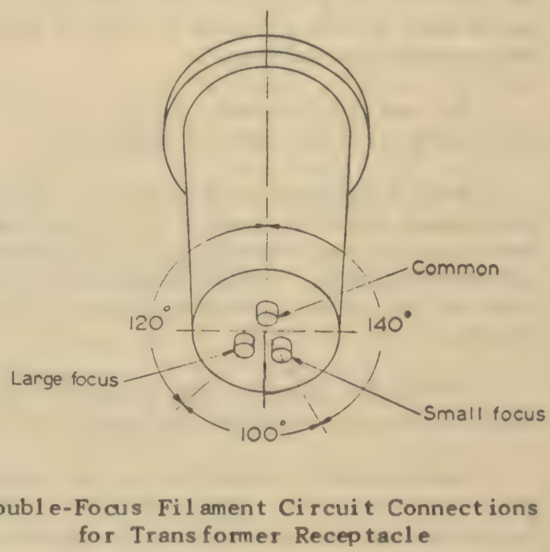
Cable replacement. In case of cable failure, a complete cable equipped with all terminal fittings should be obtained from the factory or service depot. In ordering the replacement cable, specify type of tube for which it is to be used, single or double-focus, whether for anode or cathode side, and type of terminal fittings.

Attach the replacement cable in the manner described above under INSTALLATION.

A—Socket Insulator
B—Mounting Flange
C—Socket Insulator Holding Nut
D—Cable Insulator
E—Cable Grounding Flare
F—Cable Nut
G—Cable Guard
H—Transformer Top
I—Vapor-proofing Gasket



Cable Terminal Arrangement for Direct Connection to Transformer



Double-Focus Filament Circuit Connections for Transformer Receptacle

INSTRUCTIONS FOR INSTALLATION, OPERATION, AND MAINTENANCE OF THE PICKER OIL IMMERSED SHOCKPROOF AIR-FLOW TUBES

INSTALLATION - The Picker Air-flow tube is a completely shockproof oil immersed tube with an enclosed, built-in, self-contained turbine blower or fan which operates on 115 volts, 50 to 60 cycle current. The blower is built into the tube housing and provides a quiet and efficient method of cooling the tube. On the inside of the tube head is a patented oil circulator or motor-driven impeller which forcibly circulates the oil against the anode stem of the x-ray tube. This oil impeller reduces the anode operating temperature to approximately 50 percent of its normal value. This, of course, is a very efficient method of removing the heat from the anode stem and transferring it to the grounded metal shell of the x-ray tube. This naturally increases this temperature of the outer shell, which then can be efficiently cooled by the turbine blower or fan, mentioned above, which blows air over the outside of the tube head proper. The PX-3B and PX-3X series of tubes are provided with a 20 degree target angle. The PX-3A tube has a 30 degree target angle tube and is intended for superficial therapy work only. They are available in a variety of focal spots with tube ratings as listed hereafter. *The focal spots must be specified.* The tubes are available in either single-focus or double-focus models. The focal spot available are:

A - 1.5 mn.	AC+	1.5 mn.
B - 2.3 mn.		3.8 mn.
C - 3.2 mn.	BC+	2.3 mn.
C+- 3.8 mn.		3.8 mn.
D - 4.2 mn.	BD	2.3 mn.
E - 5.0 mn.		4.2 mn.

The PX-3B tube may be used on the Century, Comet, or Picker Radiographic tubestand style H, G, or GX, or Bi-Rail. When used on the Century and Comet units a yoke type tube hanger Figure B, is used with a cone base holder, Figure C, while a mounting plate, Figure A, is used on the radiographic type tubestand. No cone base holder is needed with this type "A" mounting as the tubestands are already provided with a cone and filter holder.

The PX-3B tube weighs approximately 22 pounds without the hanger - shipping weight is 29 pounds. The increased weight of the PX-3B tube over the PX-1B tube, which is approximately 12 pounds, necessitates adjustment in the counterbalancing of the tubestands and the tables wherever it is used.

For substituting the PX-3B tube on the Century tables, the tube hanger, tube arm, special counterweight, and cone base holder are included in assembly number #9039-A. For substituting the PX-3B tubes on Comet units all necessary parts are included in assembly #9044. In the case of the type "A" mounting, only the mounting plate #26275-A is needed.

ELECTRICAL CONNECTIONS - The high-tension cables are completely shockproof and can be ordered at the same time as the x-ray tube. Be sure to state the type of tube, the type of transformer, and the length of the cables desired. When installing the cable, the ends should be thoroughly cleaned with a clean, dry rag. When inserting in the transformer ends, and the x-ray tube ends, be careful not to damage the bakelite ends of the cables. These should never be allowed to be dropped or to become broken or damaged as it will result in electrical failure.

It will be noticed that the cables have concentric terminals at the x-ray tube end so as to allow the tube or cables to be rotated in respect to each other without putting any strain whatsoever on the cable or on the cable terminations. The cathode cable for a double-focus tube has three connections. The smallest or inner contact is the large-focus filament contact. The center or intermediate contact is the common connection for both small and large-focus filaments. The outside, or largest connection, is the connection for the small-focus filament.

It is very important that the bakelite terminations of the cable and the shockproof receptacles of the PX tube housing and the transformer be thoroughly cleaned before plugging the cables into the tubehead. A small amount of carbontetrachloride can be used as a cleaning agent if necessary. A coating of white vaseline should be used on the outside of the bakelite terminals of the cables to provide the best seal between the cable end and the shockproof receptacles, and to exclude all air and moisture from the terminations.

There is no inherent means of limiting the current on the small-focus filament to prevent excessive milliamperage from being impressed on the small size focal spot of the x-ray tube. However, all Picker X-Ray Generators built since 1937 have a milliamperage limiting device in the control to limit this milliamperage on the small size focal spot of the tube, to a safe value. If you are installing a shockproof tube on generators built before this time, it is recommended that you obtain a suitable current limitor for this purpose. On generators built since 1937, it is, of course, necessary to properly adjust and regulate these devices to obtain a safe maximum limit of milliamperage on the tube.

When inserting the terminals into the shockproof receptacles of either the tube or the transformer, be sure that they are in as far as they will go, and then carefully screw on the threaded retaining caps on each end, taking care not to strip the threads.

The blower and oil circulator motors which are connected in parallel inside of this tube must be connected to a source of 115 volts, 50 to 60 cycle AC current. The function of these motors as explained before is to cool the tube. Failure to have them running properly when the tube is in operation may cause a dangerously overheated tube or even a tube failure. These tubes are normally fitted with a temperature indicating button on the anode end of the tube. When this button has been pushed out far enough by the expanding oil in the x-ray tube to show red, the tube should not be operated until it has cooled sufficiently and the red part of the indicating button has again been withdrawn within the housing. Failure to observe this will result in premature failure of the x-ray tube.

An optional safety switch Catalogue #11354 may be installed in the tube to prevent exposures on the tube after it has reached its limit of temperature. This is operated in conjunction with a relay in the control which is part of the above catalogue number, so that as the tube becomes overheated and the oil in the tube expands to its maximum limit, or either motor is not energized the safety switch will open the relay circuit and thereby prevent energizing of the high-tension primary.

It must be cautioned that while this switch will prevent overloadings of low milliamperage exposures, such as encountered in therapy or fluoroscopic work, and will prevent too frequent an operation of normal radiographic exposures, it will not prevent from an accidental high radiographic milliamperage overload because of the long time necessary for the conductivity of the heat from the actual tungsten surface of the anode to the extreme end of the anode shank and then through the oil.

Normally this switch is set for 212 degrees Fahrenheit.

TUBE OPERATION - After the tube is installed and ready for operation it should be checked carefully to see that the cables are properly installed - the blower cable is connected to the proper voltage, and if the tube is equipped with a temperature safety switch, it is properly plugged into the receptacle provided on the x-ray tube. Next, carefully check the x-ray tube rating for the focal spot selected. These ratings are conservative, but the actual exposure time should not be exceeded. Too much emphasis cannot be made, nor too much attention cannot be paid to these rating charts and the dangers of exceeding x-ray tube ratings. Be absolutely sure that the rating chart selector is the correct one for the size focal spot and the type of circuit on which it is being used. The air-flow tube has a heat storage capacity of 250,000 heat units, that is, P.KV. times M.A. times seconds. The radiation rate at maximum temperature is 25,000 units per minute. During any one hour the heat storage capacity may be as high as 500,000 heat units. Do not operate the tube, however, when the red bakelite indicator on the end of the tube appears. This means that the tube has reached its maximum temperature and cannot be operated until it has cooled further. The fluoroscopic rating of the tube on self-rectified, half-wave or full-wave circuit is 5 M.A. at 85 P.KV. continuously, or 4 M.A. at 100 P.KV. continuously. On self-rectified circuits, it is recommended that the kilovoltage should not exceed 90 P.KV. to prevent exceeding the 100 P.KV. maximum inverse voltage rating of the x-ray tube, and also to further lengthen the life of the shockproof cables on this AC or unrectified current.

MAINTENANCE - The air-flow tube housing has been designed to give a maximum life with a minimum of servicing or maintenance. It is tested at voltages in excess of its ratings, and it has been designed to meet a wide range of operating conditions. The only maintenance that should be required is the occasional replacement of the tube insert when its useful life has expired or the replacement of shockproof cables which may occasionally break down under certain conditions of use, An occasional oiling of the external motor blower should be made with a high grade light machine oil such as 3 in 1.

THE REPLACEMENT - The x-ray tube is mounted and sealed in its housing. When failure occurs or replacements for any reason are necessary, the entire air-flow tube housing must be returned to the factory. Tube failure may be caused by an excessively high-voltage, either a high-inverse, or a high-surge voltage, which may result in the tube becoming prematurely gassy or punctured - overloading of the focal spot either by too high a milliamperage for a short time or too long operation on a low milliamperage slightly above the continuous rating. In order to insure correct operation and prevent tube failure the following items should be checked: Exposure ratings of both fluoroscopic and radiographic values should be checked with the chart and the focal spot size and type of generator. The milliammeter should always be checked on installation of a new tube, or a replacement tube, preferably with a larger meter of definitely known accuracy, temporarily placed in the anode high-tension circuit, by use of special plug adapters for this purpose. Kilovoltage should be checked with sphere gap or other known means.

CABLE REPLACEMENT - In case of high-tension shockproof cable failure a whole new cable must be obtained.

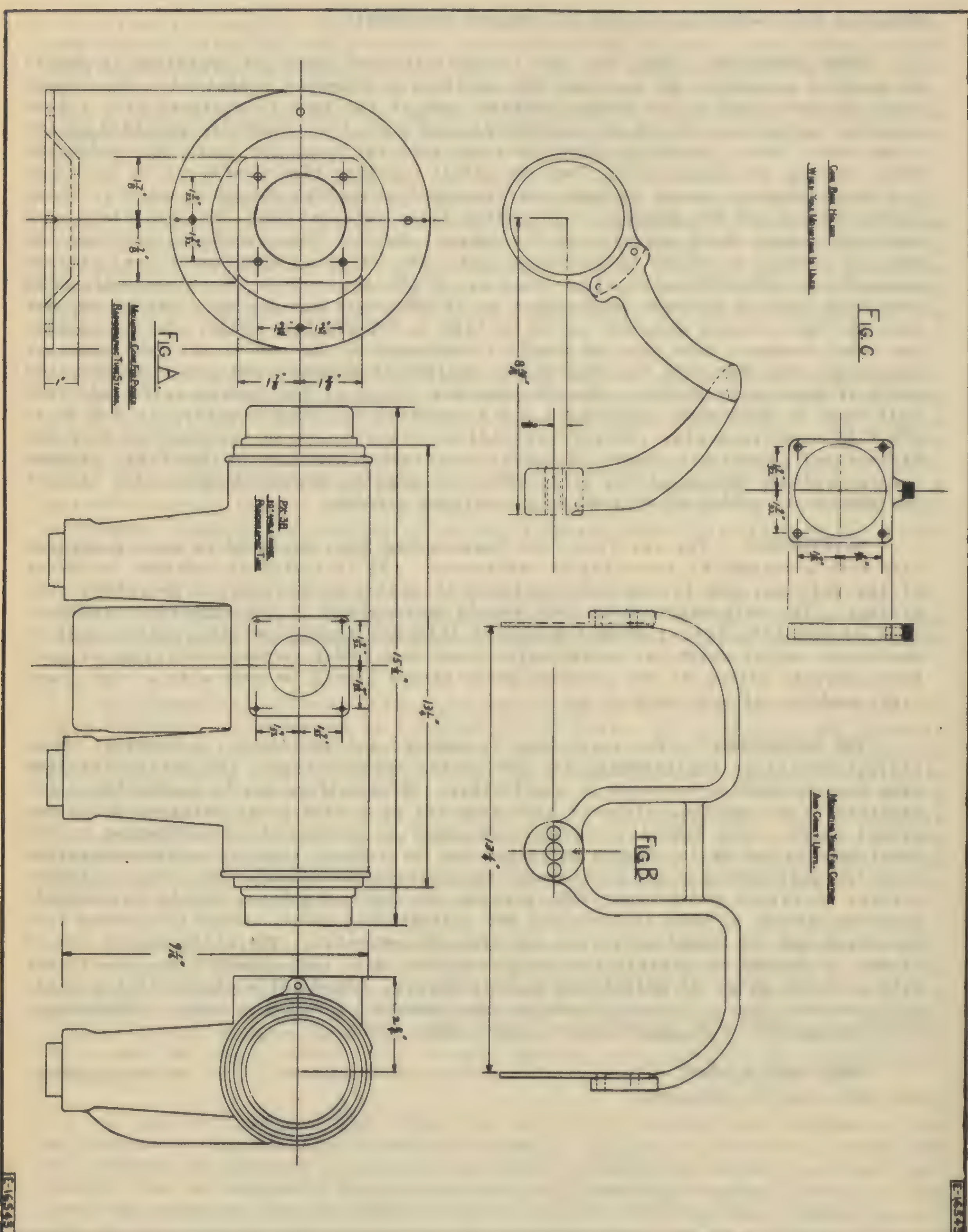
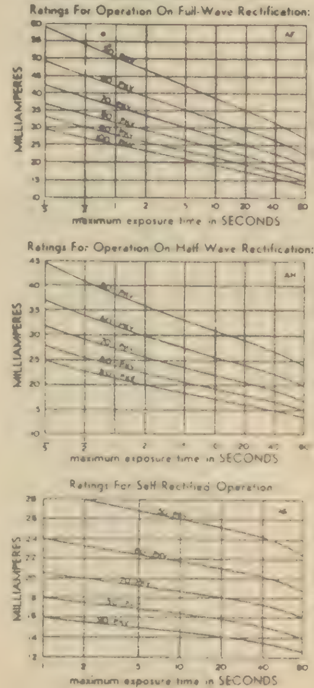


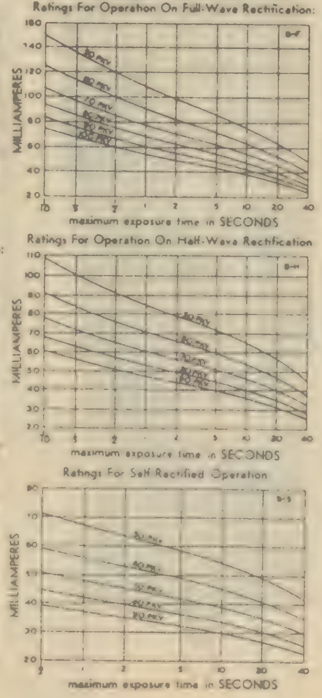
Fig. A
Fig. B
Fig. C

RATING CHARTS FOR PX-3B & PX-3C TUBES

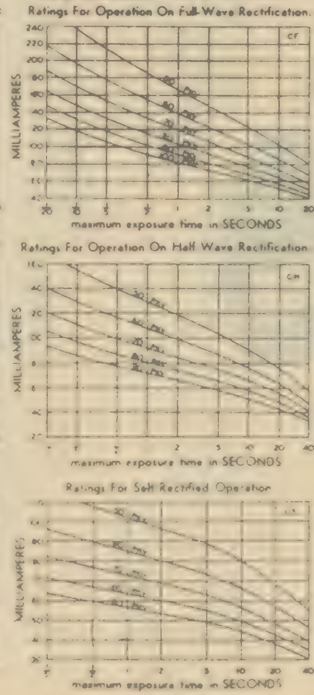
"A" FOCAL SPOT
Effective Size — 1.5 m.m.
Filament Characteristics —
3.5 to 4.5 Amps. 3.0 to 4.0 Volts



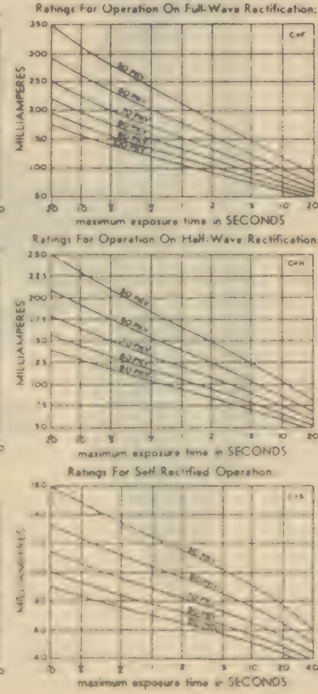
"B" FOCAL SPOT
Effective Size — 2.3 m.m.
Filament Characteristics —
3.7 to 4.7 Amps. 3.5 to 5.0 Volts



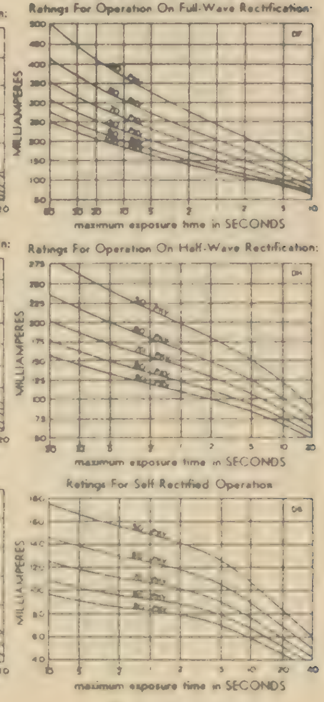
"C" FOCAL SPOT
Effective Size — 3.2 m.m.
Filament Characteristics —
4.0 to 5.0 Amps. 5.0 to 7.0 Volts



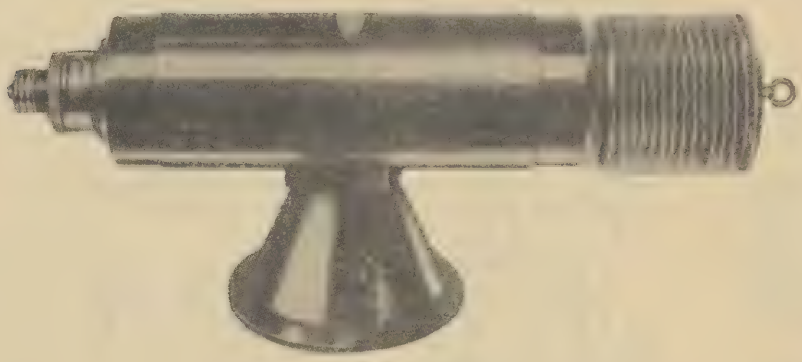
"C PLUS" FOCAL SPOT
Effective Size — 3.8 m.m.
Filament Characteristics —
4.0 to 5.0 Amps. 5.0 to 8.0 Volts



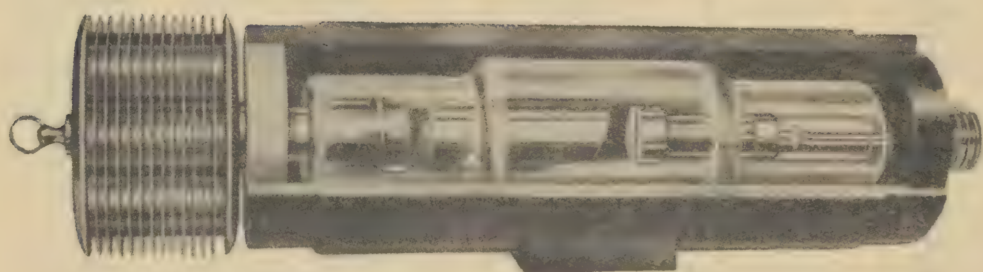
"D" FOCAL SPOT
Effective Size — 4.2 m.m.
Filament Characteristics —
4.0 to 5.2 Amps 5.5 to 9.0 Volts



In the CYR, auto-protection has been incorporated into a unique principle of construction which makes possible a more compact tube of greater ruggedness and higher capacity with air cooling. This principle is illustrated below by a photograph of a CYR tube with a section of its rayproof housing cut away to show the internal construction. Note that the Pyrex glass tube is permanently mounted in an insulating X-Rayproof housing, being supported entirely by the anode shank. Thus, no end-caps on the tube itself are necessary for support or connections. The overall length for the required creepage distance is therefore reduced to a minimum, resulting in the unusually *short* and *compact* design.



THE CYR



CYR Tube with section of Rayproof Housing Cut Out to Show Internal Construction.

In order to make the advantage of CYR features available for all classes of diagnostic work, a number of types have been standardized, each type being best suited for a particular range of applications. First, there are a number of different focal spot sizes, making it possible to select a tube having as fine a focus as will permit the use of the required techniques and thus obtain the finest possible detail in each case. These various focal sizes may be obtained either in single-focus CYR tubes or combined by pairs in double-focus CYR tubes. The entire

CYR series is also divided into two sub-divisions, a HEAVY DUTY Series and a Standard Series. The significant features of each of these different types of CYR tubes are identified in the descriptions which follow.

The different focal spots available, with their designations, effective sizes, and the approximate maximum milliamperage techniques for which each is suitable, are listed in the following table:

Single-Focus Tubes			Double-Focus Tubes		
Designation	Projected Size	Techniques	Designation	Projected Size	Techniques
"A"	1.5 mm.	10- 20 MA		1.5 mm.	10- 20 MA
"B"	2.3 mm.	30- 50 MA	"AC plus"		
"C"	3.2 mm.	60-100 MA		3.8 mm.	100-200 MA
"D"	4.2 mm.	100-300 MA		2.3 mm.	30- 50 MA
"E"	5.0 mm.	150-500 MA	"BD"		
("E" focal spot available in HEAVY DUTY Series only.)				4.2 mm.	100-300 MA

With double-focus CYR tubes, a selector switch is provided on the tube for selecting the focus desired. A protective reactor is built into the tube, in series with the filament for the smaller focus, to limit the current in case an attempt is made, through error, to use the small focus for a technique intended for the large focus.

CYR Tubes are mounted on the conventional tube stand by means of a conical adapter, the dimensions of which are given hereafter.

All CYR Tubes can be made shockproof by the addition of an air-cooled shockproof shield with cables, which has been specially designed for use with these tubes.

RATINGS AND SPECIFICATIONS

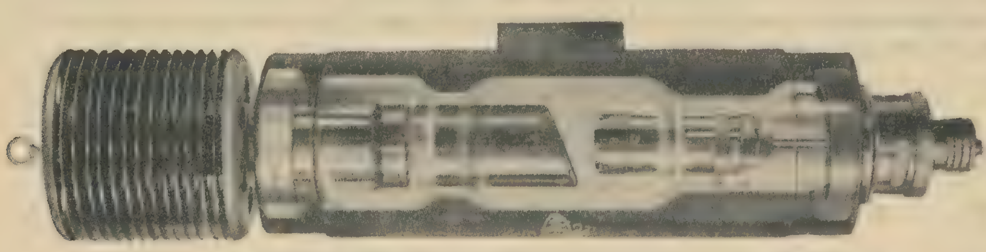
MAXIMUM VOLTAGE RATINGS - 100 PKV.

MAXIMUM ENERGY RATINGS - The maximum allowable energy load for exposures of any given duration is largely determined by the size of the focal spot. The ratings corresponding to each of the different focal spot sizes in the various types of CYR tubes are given over a wide range of exposures by the charts on the following pages.

FLUOROSCOPIC RATINGS - CYR (Standard Series)..... 85 PKV, 5 MA, 10 minutes
HEAVY DUTY CYR............ 85 PKV, 5 MA, 20 minutes

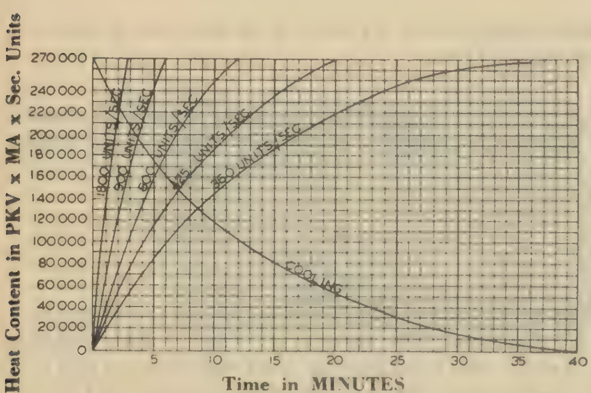
THERMAL CHARACTERISTICS - In CYR tubes, the construction feature which reduces the overall length also permits the use of an anode design which results in an unusually high rate of heat dissipation. A short thick anode provides a path of high thermal conductivity from the target to the highly efficient convection type radiator, which is threaded directly to the anode shank for better heat transfer. The accompanying charts indicate the complete thermal characteristics of CYR tubes

of the HEAVY DUTY Series and Standard Series respectively. These characteristics involve both the heat capacity and rate of heat dissipation of these respective types.

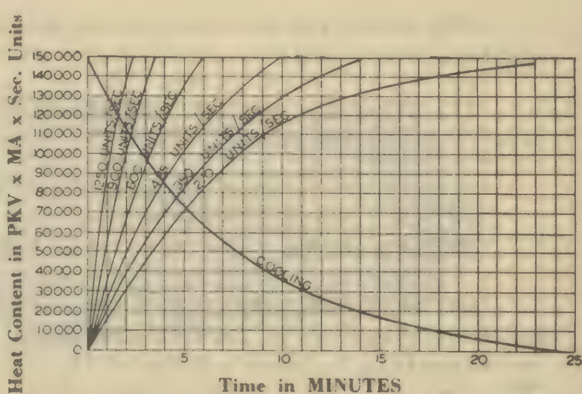


"Phantom" View of HEAVY DUTY CYR Tube Showing Massive Anode Construction.

HEAVY DUTY SERIES - The HEAVY DUTY CYR embodies a special type of anode structure in order to provide the greatest possible heat capacity and to reduce to a minimum the cooling intervals required when operating under the busiest conditions. The chart at left below gives the rate of increase in heat content for various average values of power input and the rate of heat dissipation with no input. The unit of heat used is such that the number of units represented by any exposure is the product of PKV x MA x Seconds. The maximum safe heat content of the HEAVY DUTY CYR is 270,000 units.

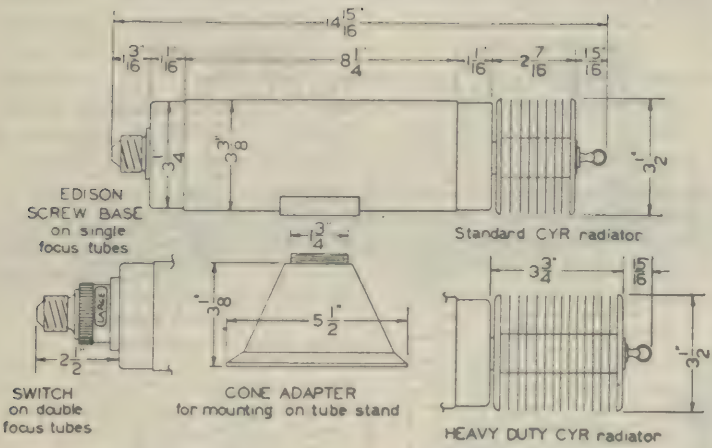


Thermal Characteristics of HEAVY DUTY CYR.



Thermal Characteristics of Standard CYR.

STANDARD SERIES - The Standard CYR has heat capacity of 150,000 units, which is more than adequate for the requirements of the average user. The same high quality of radiographic results obtainable with the HEAVY DUTY CYR tubes may be also obtained with the tubes of the standard series, and the rapid cooling rate makes the necessary cooling intervals unusually short. The chart at right provides the information necessary to calculate the cooling intervals required under any given set of conditions. Where the nature of the usage permits the necessary cooling intervals, the Standard CYR tubes can be used with worthwhile economy.



Dimensional Data--CYR Series

Example of use of Thermal Characteristics curves to determine whether or not a given operating schedule will overheat the tube and to calculate the necessary cooling intervals.

(This example refers to the HEAVY DUTY CYR characteristics given in figure on the preceding page.)

Assume that a number of sinus exposures are to be taken in rapid succession, each exposure being 30 MA, for 5 seconds, at an average of 70 PKV. These exposures are to be made at the rate of 2 per minute and it is desired to ascertain how long this procedure may be continued before it is necessary to stop to avoid overheating the tube. This constitutes a load of 30 x 70 x 5 x 2 = 21,000 heat units per minute, or 350 units per second. The chart indicates that a load of 360 units per second may be carried continuously at the maximum heat content of 270,000 units: hence, the assumed exposures can be made at the rate of 2 per minute indefinitely. However, if lateral lumbar spine exposures at 30 MA, 90 PKV, 10 seconds are to be made at this rate, the calculation shows that the average power input is 30 x 90 x 10 x 2 = 54,000 units per minute or 900 units per second. This rate of input may be maintained for not more than six minutes, starting with a cold tube. If further exposures are to be made, the tube must be allowed to cool until its heat content has fallen to a point from which the additional exposures will not increase the heat content above the maximum safe value of 270,000 units.

Type	Catalog No.
CYR-A	C-314
CYR-B	C-315
CYR-C	C-316
CYR-D	C-317
CYR-AC plus	C-322
CYR-BD	C-324
HEAVY DUTY CYR-A	C-326
HEAVY DUTY CYR-B	C-327
HEAVY DUTY CYR-C	C-328
HEAVY DUTY CYR-D	C-329
HEAVY DUTY CYR-E	C-330
HEAVY DUTY CYR-AC plus	C-331
HEAVY DUTY CYR-BD	C-332
Adapter for mounting CYR tubes	C-319

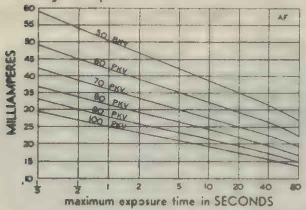
REPLACEMENTS - To order replacement tubes, without radiator and, in the case of double-focus tubes, without switch, add "A" to catalog numbers of above list: for example: CYR-BD without radiator and switch .. C-324A.

The charts below (except "E" Focal Spot) giv e ratings applying to tubes of the Standard Series. For exposures longer than 10 seconds, HEAVY DUTY CYR tubes have ratings somewhat higher than those shown. Charts showing exact ratings are furnished with each tube.

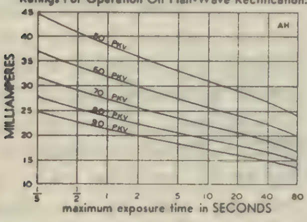
"A" FOCAL SPOT

Effective Size — 1.5 m.m.
Filament Characteristics —
3.5 to 4.5 Amps. 3.0 to 4.0 Volts

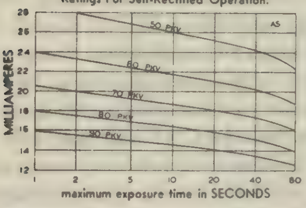
Ratings For Operation On Full-Wave Rectification:



Ratings For Operation On Half-Wave Rectification:



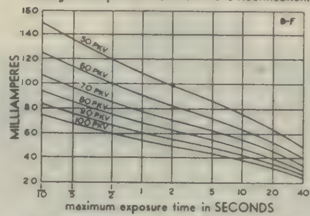
Ratings For Self-Rectified Operation:



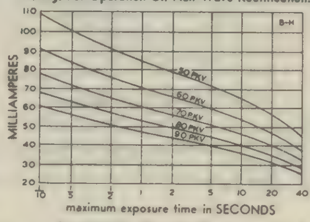
"B" FOCAL SPOT

Effective Size — 2.3 m.m.
Filament Characteristics —
3.7 to 4.7 Amps. 3.5 to 5.0 Volts

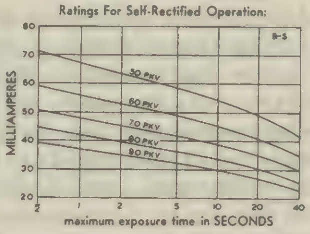
Ratings For Operation On Full-Wave Rectification:



Ratings For Operation On Half-Wave Rectification:



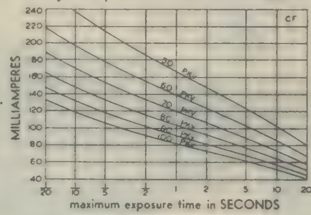
Ratings For Self-Rectified Operation:



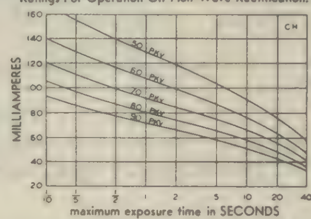
"C" FOCAL SPOT

Effective Size — 3.2 m.m.
Filament Characteristics —
4.0 to 5.0 Amps. 5.0 to 7.0 Volts

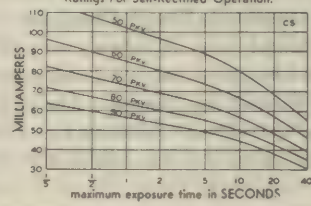
Ratings For Operation On Full-Wave Rectification:



Ratings For Operation On Half-Wave Rectification:



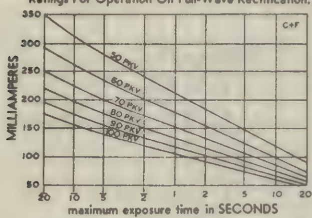
Ratings For Self-Rectified Operation.



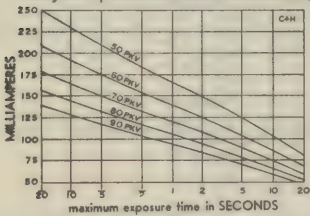
"C PLUS" FOCAL SPOT

Effective Size — 3.8 m.m.
Filament Characteristics —
4.0 to 5.0 Amps. 5.0 to 8.0 Volts

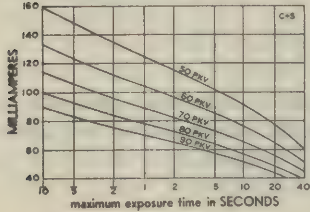
Ratings For Operation On Full-Wave Rectification:



Ratings For Operation On Half-Wave Rectification:



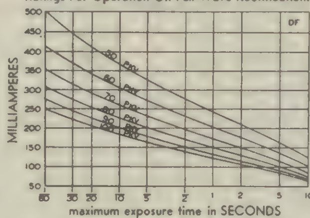
Ratings For Self-Rectified Operation:



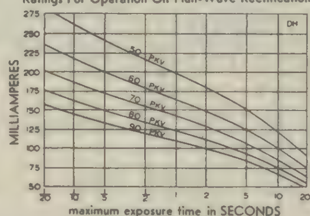
"D" FOCAL SPOT

Effective Size — 4.2 m.m.
Filament Characteristics —
4.0 to 5.2 Amps. 5.5 to 9.0 Volts

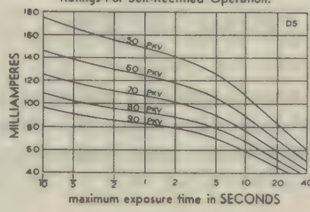
Ratings For Operation On Full-Wave Rectification:



Ratings For Operation On Half-Wave Rectification:



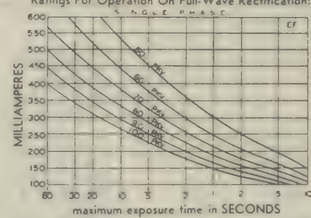
Ratings For Self-Rectified Operation:



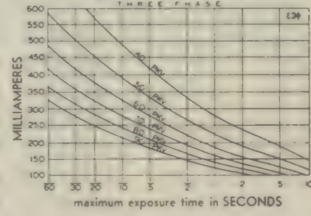
"E" FOCAL SPOT

Effective Size — 5.0 m.m.
Filament Characteristics —
4.0 to 5.5 Amps. 5.5 to 10.0 Volts

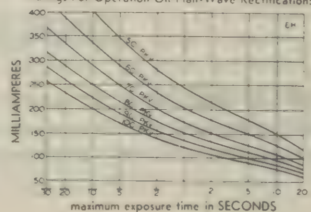
Ratings For Operation On Full-Wave Rectification:



Ratings For Operation On Full-Wave Rectification:



Ratings For Operation On Half-Wave Rectification:



THE CYS SERIES SHOCKPROOF DIAGNOSTIC TUBES

The CYS Tubes are heavy anode, line focus, Pyrex glass tubes permanently mounted in shockproof, X-Ray protective, oil-filled enclosures equipped with removable, extremely flexible shockproof cables. These tubes are constructed in accordance with the Machlett principle of oil-immersed shockproof tube design, whereby the total size and weight required for a given operating capacity are reduced by approximately one-half. This compactness is achieved by the combination of a vacuum treatment and sealing process of the oil in the tube head, and an exclusive feature in the construction of the tube itself which eliminates the catalytic action of the anode material in promoting degeneration of the oil. The resulting small size and light weight combined with high operating capacity make these tubes extremely well adapted to shockproofing a very wide range of types of diagnostic equipment.

The CYS
The small, compact, powerful shockproof diagnostic tube with full capacity for all diagnostic applications, yet extremely lightweight for universal adaptability.

CYS TYPES FOR VARIOUS APPLICATIONS - The CYS tubes are available in a wide selection of focal spot sizes, making it possible to select a tube having as fine a focus as will permit the use of the required technique and thus secure the finest possible detail in each case. Five different focal sizes have been standardized, available in both single-focus types and double-focus combinations. These focal spots, with their designations, effective size, and the approximate maximum milliam-

perage techniques for which each is suitable, are listed in the following table. Complete rating information on all types is given hereafter.

Single-Focus Tubes			Double-Focus Tubes		
Designation	Projected Size	Techniques	Designation	Projected Size	Techniques
"A"	1.5 mm.	10- 20 MA	"AC plus"	1.5 mm.	10- 20 MA
"B"	2.3 mm.	30- 50 MA		3.8 mm.	100-200 MA
"C"	3.2 mm.	60-100 MA	"BC plus"	2.3 mm.	30- 50 MA
"C plus"	3.8 mm.	100-200 MA		3.8 mm.	100-200 MA
"D"	4.2 mm.	100-300 MA	"BD"	2.3 mm.	30- 50 MA
				4.2 mm.	100-300 MA

Each of the focal sizes and double-focus combinations listed above is available in either the standard CYS type, with cables projecting vertically from the top of the tube, or the Right Angle CYS type, with the cables projecting horizontally from the side of the tube. The arrangement of the cables of each type is indicated by the dimensional sketch shown hereafter.

INSTALLATION - The CYS tube is designed to mount directly on the tube carriage of most types of tube stands generally in use. It is supplied with a mounting cone which permits it to be mounted in the same manner as the conventional lead glass bowl on the usual tube stand. This mounting cone is removable, permitting the attachment of any special mounting arrangement as desired.

Connections to the source of filament current and high-tension are made by means of shockproof cables, which are supplied with proper terminals for connection to the tube at one end and, unless otherwise specified, to an overhead aerial circuit at the other. Ceiling insulators are provided, when specified, for supporting the cables in cases where it is not feasible to connect the terminals direct to the aerial tubing. A cord-operated ceiling switch is available for focus selection in double-focus models.

Special cable terminals, for connecting direct to transformer or for other special arrangements, will be furnished if practicable upon requests accompanied by proper instructions.

REPLACEMENTS - The CYS tube heads are complete factory sealed and tested units. When tube replacement becomes necessary, the cables are detached and the entire head is replaced, proper allowance being made for the enclosure on its return to the factory. The cables, being detachable, can be replaced independently when required.

RATINGS AND SPECIFICATIONS

MAXIMUM VOLTAGE RATINGS - Fully rectified (2 or 4-valve or mechanical rectification) ....100 PKV
Single-valve or self-rectified .... 90 PKV

MAXIMUM ENERGY RATINGS - The maximum allowable energy load for exposures

of any given duration is largely determined by the size of the focal spot. The ratings corresponding to the five different focal spot sizes are given over wide ranges of exposure values by the charts shown hereafter.

FLUOROSCOPIC RATING - Ten minutes at 85 PKV and 5 MA.

THERMAL CHARACTERISTICS - Heat Storage Capacity: 250,000 units (PKV x MA x Seconds).

Radiation rate at maximum temperature: 5000 units per minute.

(Note: A built-in indicator shows when maximum safe temperature has been reached.)

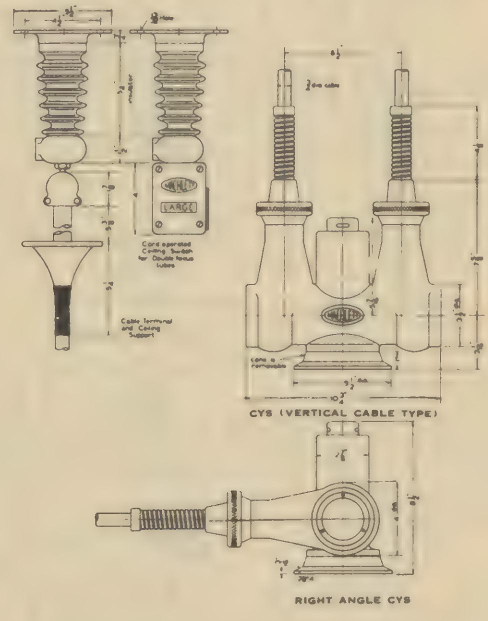
DIMENSIONAL

DATA

CYS

Shockproof

TUBES



Weight to be Supported, with Cables Suspended: 15 lbs.

Standard Cable Length: 8 ft.

(Any desired length will be furnished at extra cost).

ORDERING INFORMATION:

Type	Catalog No.
CYS-A	C-351
CYS-B	C-352
CYS-C	C-353
CYS-C plus	C-349
CYS-D	C-354
CYS-AC plus	C-356
CYS-BC plus	C-359
CYS-BD	C-357
Right-angle CYS-A	C-371
Right-angle CYS-B	C-372
Right-angle CYS-C	C-373
Right-angle CYS-C plus	C-369
Right-angle CYS-D	C-374
Right-angle CYS-AC plus	C-376
Right-angle CYS-BC plus	C-379
Right-angle CYS-BD	C-377
Ceiling Supports for CYS Cables	C-350
Ceiling Switch for use with Double-Focus CYS Tubes	C-360

Replacements:

To order replacement Tube Heads, without cables, add "A" to catalog numbers of above list; for example:

CYS-A without cables	C-351A

Cables:

Cable for Single-focus CYS	C-355
Anode Cable for Double-focus CYS	C-362
Cathode Cable for Double-focus CYS	C-358

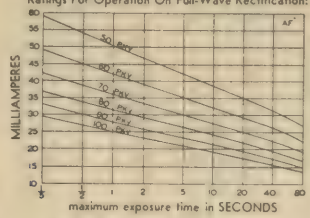
Rating Charts—CYS Series

These charts should be used as a guide in the selection of the proper focal size for any radiographic application. The finest focus whose rating will not be exceeded by the required technique should always be selected.

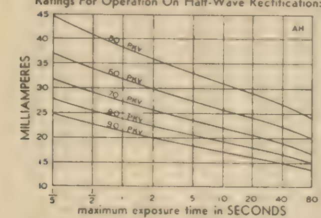
"A" FOCAL SPOT

Effective Size — 1.5 m.m.
Filament Characteristics —
3.5 to 4.5 Amps. 3.0 to 4.0 Volts

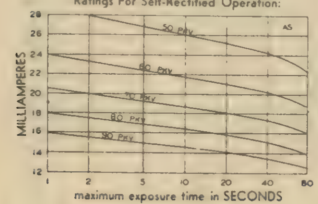
Ratings For Operation On Full-Wave Rectification:



Ratings For Operation On Half-Wave Rectification:



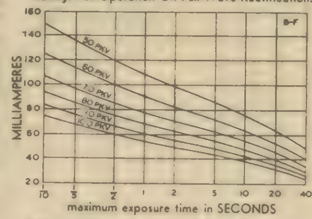
Ratings For Self-Rectified Operation:



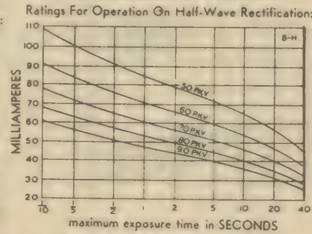
"B" FOCAL SPOT

Effective Size — 2.3 m.m.
Filament Characteristics —
3.7 to 4.7 Amps. 3.5 to 5.0 Volts

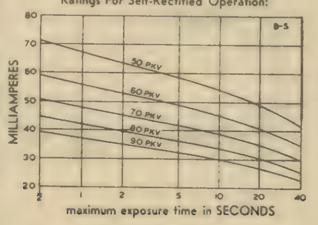
Ratings For Operation On Full-Wave Rectification:



Ratings For Operation On Half-Wave Rectification:



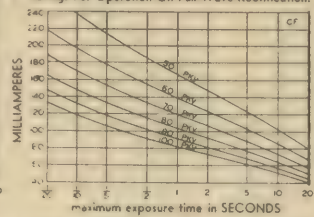
Ratings For Self-Rectified Operation:



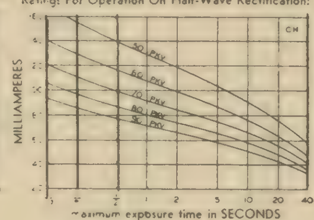
"C" FOCAL SPOT

Effective Size — 3.2 m.m.
Filament Characteristics —
4.0 to 5.0 Amps. 5.0 to 7.0 Volts

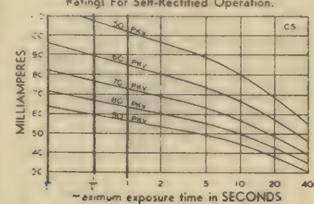
Ratings For Operation On Full-Wave Rectification:



Ratings For Operation On Half-Wave Rectification:



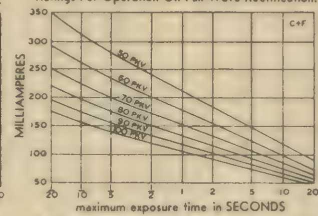
Ratings For Self-Rectified Operation.



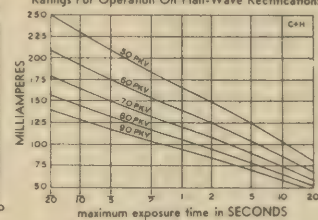
"C PLUS" FOCAL SPOT

Effective Size — 3.8 m.m.
Filament Characteristics —
4.0 to 5.0 Amps. 5.0 to 8.0 Volts

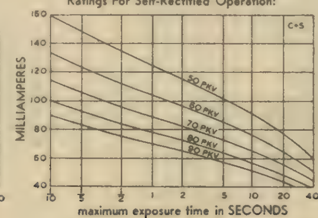
Ratings For Operation On Full-Wave Rectification:



Ratings For Operation On Half-Wave Rectification:



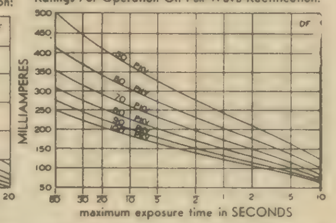
Ratings For Self-Rectified Operation:



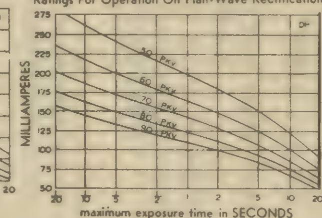
"D" FOCAL SPOT

Effective Size — 4.2 m.m.
Filament Characteristics —
4.0 to 5.2 Amps. 5.5 to 9.0 Volts

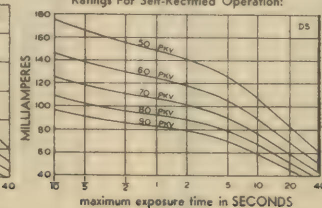
Ratings For Operation On Full-Wave Rectification:



Ratings For Operation On Half-Wave Rectification:



Ratings For Self-Rectified Operation:



DIRECTIONS FOR INSTALLING THE GENERAL ELECTRIC SHOCKPROOF DIAGNOSTIC CASING

1. These directions present a tried and approved method of installation and it is therefore important that they be carefully read.

NOTE: Since this casing may have encountered subnormal temperatures while enroute or in storage, it must be inspected for the presence of air. This must be removed before operating the unit. See paragraph 81 for details.

2. If the DX Shockproof Tube Unit is to be mounted on a tube stand other than the ones described herein, then the counter-balancing arrangement, proper cable support and the rigidity of the tube stand must be considered.

3. In the event any question arises, feel free to write the Medical Supply Services School, St. Louis, Mo. for assistance.

4. GENERAL - The DX tube unit is shipped completely assembled and no further adjustments are necessary. The shockproof cables which have been removed are of the "plug-in" type which affords a simple and convenient means of assembly to the tube unit. The total weight of the tube unit is slightly under 20 pounds, with the shockproof cables attached.

NOTE: All DX casings which are furnished for mounting on tube stands, will have the adapter casting Fig. 6, Illustration 3, and the ornamental end caps Fig. 85, removed for shipment.

5. The adapter casting shall be fastened to the DX casing with the four machine screws furnished.

6. The ornamental end caps shall be placed on the end of the casing, and fastened in place with the three small binding head machine screws provided.

7. The DX tube unit and its associated parts when unpacked, shall be placed on soft paper or padding material to protect the finished surfaces.

8. MOUNTING THE DX TUBE UNIT ON G.E. MODEL #6 AND #16 TUBE STANDS - Remove the x-ray tube unit, and the lead glass bowl if open type is used, and position the DX casing as shown in Illustration 3. Fasten the DX tube unit in place, using the same mounting studs which held the former tube unit. Make sure that each stud fits over the flange of the casing.

9. No support is required for the shockproof cables, and no change need be made in the counter-balancing arrangement.

10. Information for fastening the shockproof cables to the tube unit will be found elsewhere in these directions.

11. WHEN DX TUBE UNIT IS USED ON MODEL #22 TUBE STAND - When the DX Tube Unit is used on a Model 22 Tube Stand, it shall be positioned as shown in Illustration 3, and fastened in place in the same manner as the tube unit which it is replacing.

12. The cables shall be supported in the manner shown in Illustration 3. The cable support casting Fig. 67 is fastened to the weight box on the vertical carriage by means of two screws Fig. 66, one on each side. The 5/8"-10-32 fillister head machine screw Fig. 175, shall now be inserted through the hole in the lower half of the split casting Fig. 65, as shown in detail. Two small felt washers Fig. 176 are supplied which shall be placed between the casting Fig. 65, and the weight box. Draw the

screw Fig. 175, up firmly.

NOTE: In some cases it will be necessary to provide a tapped hole in the weight box for the screw Fig. 175. Spot this hole, through the hole in the casting Fig. 65, when the casting is in place. Use a #20 drill and tap the hole for a 10-32 machine screw.

The weight box cover is removed and the supporting casting installed in its place. Position the cables in the casting Fig. 67, and install the upper portion Fig. 64, securing it in place with the machine screws provided.

13. When the DX tube unit is used with the Model #22 Tube Stand, the following counterweights shall be used inside the tube stand column.

1 -weight 25-1/2" long
1 -weight 4-1/4" long
*1 -weight 4-1/4" long

Where the tube stand is already installed, the tube stand must be removed from its mounting before the additional weight unit can be placed. To remove the tube stand from its mounting, raise the tube carriage as far up as it will go locking it in that position, then remove the carriage from its vertical supporting sleeve at the point where it swivels. Loosening the two set screws in the hexagonal lock screw of the swivel stud will permit removal of this nut. Note the order and position in which the washers which are held by this nut will be found, so that they are later replaced in their proper order. Then carefully pull the tube carriage off the swivel stud. The total weight of the tube stand has now been sufficiently reduced, so that it may be lifted out of its mountings and slowly placed in a horizontal position. With the tube column in its horizontal position, loosen the set screw in the lower nut Fig. 69, Illus. #1 and remove the nut. Slide the additional weight unit on the rod Fig. 70, and replace the washer, Fig. 71, and the nut Fig. 69, locking the set screw in this nut securely. Replace the tube stand column in its mountings firmly tightening all bolts and clamps. Replace the tube carriage over the swivel stud. Replace the fibre then the steel and finally the two cup-shaped spring washers with their convex surfaces to the outside over the swivel stud. Replace the nut and tighten it to obtain the desired friction, then lock the set screws in this nut firmly.

15. WHEN DX TUBE UNIT IS USED WITH MODEL #31 TUBE STAND - Mounting of the DX tube unit will be the same as for the Model #6 and #16 Tube Stands, which is described under that section of these directions.

16. The same method of supporting the shockproof cables is used as described for the Model #22 Tube Stand.

17. The correct number and size of counterweights to be used when the DX tube unit is used with the Model #31 Stand, shall be as follows:

1-weight 25-1/2" long
1-weight 11-1/2" long which shall be cut down to 6"
**1-weight 4-1/4" long

*Used only when vertical stereo-shifter is installed on stand, otherwise omitted.
**Used only when vertical stereo-shifter is mounted on stand.

18. WHEN DX CASING IS USED WITH MODEL #30 TUBE STAND - The mounting of the DX tube unit on the Model #30 Stand, shall be the same as for the Model #31, except the counterweight assembly shall consist of the following:

1-weight 25-1/2" long cut down to 7"
1-weight 26-1/2" long
*1-weight 4-1/4" long

19. WHEN DX CASING IS USED WITH MODEL #33 TUBE STAND - No cable supporting casting Fig. 67, Illustration 3, is used in this case. The cables shall be installed over the regular cable rollers formerly used.

20. The DX tube unit shall be mounted in the same manner as described for the Model #22 Tube Stand.

21. The counterweight assembly shall consist of the following:

1-weight 12-1/2" long
1-weight 3-1/2" long
1-weight 7" long

22. Additional refinement in counter-balancing can be obtained by means of the auxiliary weights in the tubular weight boxes on the vertical carriage.

23. MOUNTING THE DX CASING ON THE MODEL #39 TABLE - The DX casing will be furnished with the end scales Fig. 81, Illustration 4, and the measuring scale Fig. 86, removed.

24. Fasten the two indicating scales Fig. 81, on the casing. These scales shall be positioned so that "O" on the scale, when aligned with the indicator mark on the fork, will position the casing level as shown.

25. The mounting holes in these end scales are slotted to afford a means of adjusting them to give correct indication of the tube angulation.

26. Mount the measuring scale Fig. 86, in the front of the casing using the machine screws provided.

27. Position the horizontal tube carriage out to the side of the table and lock it at a convenient level.

28. Be sure that all parts of the tube stand are securely locked in place before any attempt is made to install the casing.

29. Remove the two clamps Fig. 75 and Fig. 83, Illustration 4, by taking out the screws Fig. 73 and Fig. 77, and the locking handle and screw Fig. 78 and 79. With the exception of the locking screw Fig. 78, these screws are locked in place by set screws in the fork. Make sure that these set screws are loose before attempting to remove the screws which hold the clamp.

30. Place the DX casing in the fork as shown in Illustration 4, with the G.E. monogram at the front. With the casing in this position, install the clamps Fig. 75 and Fig. 83 and the screws which hold them.

*Used only when vertical stereo-shifter is mounted on stand.

31. Do not tighten the screws Fig. 73 and Fig. 77, securely. These screws shall be drawn up evenly and only enough so that the clamp fits snugly, but not tight. The screw Fig. 79, shall be tightened far enough so that the locking screw Fig. 78, will tighten firmly against the tube unit.

32. Test the tube unit to see that it moves freely back and forth in the fork. After the screws have been adjusted to give correct operation, lock them in place with the set screws provided in the fork.

33. The shockproof cables shall then be installed in accordance with the information given elsewhere in these directions.

34. Information pertaining to the Model #39 Table will be found in the directions supplied with that unit.

35. MOUNTING THE DX CASING ON THE MODEL #43 TUBE STAND (FOR R-38) (Refer to Illustration 4A) - The DX casing will be furnished with the end scales Fig. 29, and the measuring scale Fig. 31, removed. Fasten the two end scales on the casing. Fasten them so that "O" on the scale when aligned with the indicator mark on the fork, will position the casing level as shown.

36. The mounting holes in these end scales are slotted to afford a means of adjusting them to give correct indication of the tube angulation.

37. When used with a Model #43 Tube Stand, as part of an R-38 installation, a shutter and cone adapter casting Fig. 38, is furnished which must be installed on the casing.

38. The lead diaphragm, Fig. 37, is also furnished which must be installed in the casing in place of the one found already installed. These units shall be installed as follows:

39. Remove the cone adapter ring which will be found in place on the casing, by taking out the 4 machine screws which hold it in place.

40. The shutter and cone adapter casting Fig. 38, shall now be fastened to the casing as shown, using the 4-3/8" flat head machine screws provided.

41. The cone adapter ring Fig. 40, which was just removed from the casing, shall now be fastened to the casting Fig. 39, using the same screws as were used to fasten it to the casing.

42. When cones are used, the adapter Fig. 39, is fastened to the casing by inserting the studs Fig. 41, in the holes as shown, and then anchored in place with the thumbscrew Fig. 42.

43. If the shutter unit is used, it fastens to the casing in the same manner as the cone adapter.

44. The shockproof cables shall be placed in the cable supporting bracket Fig. 35, as shown. Connections for the shockproof cables at the high-voltage transformer are explained fully in direction #11075 accompanying that unit.

45. MOUNTING THE DX CASING ON THE MODEL #44 MONORAIL TUBE STAND - The tube stand will be shipped properly counter-balanced for the DX tube unit. The tube unit shall be fastened to the tube stand in the same manner as described for the Model 22

Stand. The shockproof cables shall be placed in the roller brackets. The ceiling type cable support used with the 44 Tube Stand is described in the direction supplied with the tube stand.

45A. MOUNTING THE DX CASING ON THE MODEL #40 TUBE STAND - Mounting of the DX casing on the Model 40 tube stand is the same as that for the Model #22 tube stand. No counter-weight adjustment is necessary on the Model #40 stand when used with the DX tube unit.

46. PLACING THE HIGH-VOLTAGE OVERHEAD SUPPORTS - The high-voltage overhead supports consist of an anode post Fig. 7 and a cathode post Fig. 8, Illustration 1. The cathode post can be identified by the double-focus switch, Fig. 9.

47. To fasten the insulating posts to the ceiling, remove the base plates Fig. 10, from the flanges Fig. 12, and fasten the base plates to the ceiling so that they will be positioned as shown in Illustration 1. Use expansion or toggle bolts, depending upon the construction of the ceiling.

47A. Fasten the insulating posts Fig. 11, to the base plates by means of the adapter flanges Fig. 12, making certain that the openings for the overhead tubing are facing in the correct position. Before attaching the shockproof cables to the insulating posts, see that they are not twisted, and that they hang freely.

NOTE: The standard cables are satisfactory for all ceiling heights not exceeding 11 ft. It will be necessary to order special lengths of shockproof cables or special length upper insulators, Fig. 11.

48. Remove the housing cover Fig. 13, Illustration 1, and place the swivel end of the anode cable into the lower end of the housing Fig. 14, with the swivel stop facing outward to allow the maximum amount of turning.

49. CONNECTING SHOCKPROOF CABLES TO DX CASING - Both the anode and cathode cables have been removed from the tube casing for shipment.

50. Wipe off the bakelite surfaces of the receptacle and the bushing with a cloth moistened in carbon tetrachloride. Be sure there is no moisture or foreign matter present in the receptacle.

51. Allow the parts to dry for a few moments.

52. Apply a thin even coat of fibre grease to both sides of the gasket and place the gaskets over the "plug-in" bushing. Use two gaskets for each bushing.

53. Spread "white petrolatum jelly" liberally and evenly all around the entire length of the "plug-in" bushing. There should be sufficient petrolatum to completely seal the air space in the bushing along its entire length.

54. Insert the bushing slowly into the receptacle, being careful not to damage the moulded bakelite parts. Fasten the bushing with the four 1-1/4" screws furnished.

55. Next install the ornamental rims over the flanges on the cable bushings. Each ornamental rim is split, and each pair indexed so that they will match when installed. The index figures are stamped on the inside of each rim. Each piece is held in place with two 3/8" machine screws provided.

56. When the bushings are sealed as described in the preceding paragraphs, they

may stick in the receptacles and prove difficult to remove.

57. The following procedure should be used to remove the cables so that the moulded bakelite parts are not damaged.

58. Remove the split ornamental rims. Remove the four fillister head machine screws which hold the bushing in place.

59. Insert two of these screws just removed into the two threaded holes in the top casting of the bushing.

60. Turn these screws down evenly together and the bushing will be forced out of the receptacle.

NOTE: Be sure that these two screws are turned down carefully together or the molded bakelite parts of the bushing may be damaged.

CONNECTING THE CABLES TO THE OVERHEAD SYSTEM - *NOTE: Both the anode and cathode cables furnished with the DX casing for connection to an open overhead system, are exactly alike. The anode cable receptacle on the DX casing is stamped "A" and the cathode "C". This will be the only means of identifying the cables.*

61. Connections at the anode post shall be made as follows: Fasten the three leads Fig. 15, of the anode cable Fig. 16, under the screw Fig. 17, in the housing. Refasten the cover Fig. 13, by means of the three screws Fig. 18.

62. Referring to Illustration 2, remove the housing cover Fig. 35, of the cathode post and place the swivel end of the cathode cable in the lower end of the housing Fig. 34, with the swivel stop facing outward to allow the maximum amount of turning. Remove the two screws and washers Fig. 37, and pull out the switch assembly Fig. 38, noting its position as this is being done. Solder a lug on the insulated lead Fig. 39, of the overhead filament circuit and connect it to the yellow lead Fig. 40, of the cathode cable. Bolt these two leads together using the small machine screw, nut and washer furnished. Insulate these connections with rubber and friction tape.

63. Solder a lug on the non-insulated lead Fig. 42, of the overhead filament circuit and connect it to the lead Fig. 43, of the overhead switch, using a small machine screw, nut and washer. Insulate these leads with rubber and friction tape.

64. Replace the overhead switch Fig. 38, making certain that the pin Fig. 47, in the red and white plunger engages the slot Fig. 48, in the switch blade Fig. 49, and refasten it in position with the screws Fig. 37. The two conductors Fig. 45 and 46, of the cathode cable which are stamped "S" and "L" shall be connected to the correspondingly marked terminals Fig. 50, on the switch.

NOTE: At this point, check the correctness of the "S" "L" lug markings of the cathode cable leads as follows:

65. Set the double-focus switch for the large filament (white end of plunger Fig. 27, Ill. 2, projecting) and turn on the filament adjusting the current to approximately four amperes. Disconnect the lead at "L" and replace it by the lead marked "S". Again note the current. The connection resulting in the lower filament current for the same controller setting should be "L" which is for the large filament.

66. Check the operation of the switch several times to make sure that there is no

binding or interference from the filament wires.

67. Replace the cover Fig. 35, and tighten the screws Fig. 36, taking care to see that the black cords Fig. 26, do not become entangled. Test the switch again for freedom of movement.

NOTE: When the G.E. Model "R" or the 30 ma. "F&R" X-Ray Generating Unit is to be used with the DX Shockproof Casing, it will be necessary to reduce the number of turns on the resistance winding in the overhead filament change-over switch. To accomplish this, follow the procedure as outlined below.

68. Take off the outer housing Fig. 35. Remove the screws and bakelite washers Fig. 37, and pull out the switch assembly Fig. 38, noting its position. Disconnect all wires necessary to free the switch from the housing. When doing this, note the position of the wires.

69. The next step is to remove the resistance winding Fig. 95, from the switch assembly by unscrewing the nut Fig. 96, and then remove the stud Fig. 97. Disconnect the two leads Fig. 98 and 99, of the winding noting their positions and the studs to which they are fastened. This will free the coil.

70. Cut off the finish lead Fig. 98, which protrudes from the bottom of the winding spool.

71. This lead can also be identified as the lead which is closest to the outside circumference of the spool. Pull this lead out and unwind 2 turns leaving a total of 10 turns. Be careful not to chip the enameled wire. Rethread the wire through the same hole in the bottom of the spool and pull it tight. Refasten the resistance wire winding to the switch assembly in the same position from which it was removed, and replace the stud Fig. 97 and then the nut Fig. 96. Cut the unwound portion to the proper lead length and connect both leads to their respective studs. Be sure the enamel is removed from the ends of these leads, to insure good electrical contact.

72. All wires shall be reconnected as originally, and the switch assembly fastened into place, making certain that the slot Fig. 48, engages the pin Fig. 47 of the red and white plunger Fig. 27. Replace the housing Fig. 35. Test the switch to see that the cords Fig. 26, are not tangled and that the red and white plunger functions properly.

NOTE: When the 10 ma. "F&R" Unit is used with a DX casing, follow the same procedure as above, except remove 8 turns instead of 2.

73. *NOTE: In order to check the "S" and "L" markings of the cathode cable leads when the DX-1.5-3.5 tube unit is used on an open overhead system, the following procedure must be employed.*

(1) Set the kilovoltage selector to give approximately 70 kv.p.
(2) Adjust the filament regulator to give a reading of 5 ma. on the small focal spot.
(3) Now disconnect the lead at "S" and replace it by the lead marked "L". Again note the ma. reading with the filament regulator in the same position. The connection resulting in the lower ma. reading for the same regulator setting should be "L" which is for the large filament.

74. As a final check on any of the DX double-focus tubes for correct focus spot

connections, the following tests should be made. Place the x-ray tube behind the fluoroscopic screen, adjust the shutter to as small an aperture as possible and yet present an easily visible opening to the screen. Operate the tube with the technic selector on "Radiography, Large Focus" at 10 ma. and 70 kv.p. View the image of the shutter aperture on the fluoroscopic screen noting its size. De-energize the tube.

75. Shift the technic selector to "Radiography, Small Focus". Operate the tube on small focus at the same ma. and kv.p. as above. View the image of the shutter aperture on the fluoroscopic screen and compare its dimensions with the dimensions observed above for the large focus setting. If the filaments are properly connected the image will be larger on the large focus setting. If connections are not correct, locate the error and correct it before proceeding with further tests.

76. WHEN A REMOTE FILAMENT SELECTOR IS USED (Refer to Illustration 5) - On these installations where a remote filament selector switch is used, the cathode cable support is furnished less the switch. The terminal board inside the cathode cable support will be found to have 5 terminals stamped "1", "2", "S", "L" and "C". Connect the leads in the overhead tubing as follows:

1. Connect the lead in the overhead tubing (common lead) which is connected to "C" in the transformer bushing, to the terminal "C" in the terminal board in the cathode cable support.
2. Connect the lead in the overhead tubing which connects to "S" in the transformer bushing to terminal "1" in the cathode overhead support.
3. Connect the remaining lead "L" to the terminal "L" in the cathode overhead support.

77. Connect the three leads stamped "L", "S" and "C" in the cathode cable on the DX casing to the correspondingly marked terminals in the cathode overhead support.

78. The anode cable shall be connected in the same manner as described in the preceding paragraphs under "CONNECTING THE CABLES TO THE OVERHEAD SYSTEM".

79. NOTE FOR SINGLE-FOCUS DX TUBE UNITS - On single-focus tube units, the filament leads in the casing are connected to terminals "C" and "S" on the cathode cable receptacle. Terminal "L" is not connected inside the casing. Terminal "L" is connected to the high-voltage circuit at the transformer through the high-voltage cable when used with R-2, KX-8 types 3, 4, 5, 6 and 7, KX-11 and KX-12.

79A. When a single-focus DX tube unit is used over the table with any of the above x-ray units, except the centralinear types, it will be necessary to connect terminals F-1 and F-2 on the control stand terminal board together with a jumper wire.

79B. This insures connection to the filament when the technic selector switch is moved from "Radiography, Small Focus" to "Large Focus".

79C. On older type equipment it is necessary to connect leads "S" and "L" together in the cathode cable at the overhead cable supports.

79D. IMPORTANT - Since there is no focus spot selection with a single-focus tube unit, the danger of reading the wrong scale on the milliammeter must be pointed out to the operator by the serviceman. Instruct the operator that when the technic selector is set on Radiography, Large Focus, the high scale of the milliammeter must be read. When the technic selector is set on Radiography, Small Focus, the low scale of the milliammeter must be read.

80. FINAL TEST - If the DX tube unit is used on a full-wave or half-wave two kenotron rectifier circuit, operate the tube at 100 kv.p. 2 ma. for 10 minutes; if used on a self-rectified circuit, operate at 90 kv.p. inverse, 2 ma. for 10 minutes. If there is no sound, as of sparking, the work may be considered as complete. Sparking during operation indicates the presence of air which should be removed as stated in the following paragraphs.

81. REMOVING AIR - Remove the bellows housing cap screw. Insert the bellows compression screw threading it in as far as it will go. Turn the thumb nut until it just touches the bellows housing. Extend the bellows by turning the thumb nut one or two turns. Remove the plug in the cap and insert the glass oil filler tube; back off the bellows thumb nut until oil appears in the glass tube at approximately 1/2 of its depth. If oil does not appear in the filler tube add sufficient oil to bring the level to the height required. Angulate and shake the casing as much as possible without spilling oil, frequently returning the casing to the vertical position to allow the escape of air. Also work the bellows screw in and out repeatedly to assist in the process of removing air. This operation is complete when no further air bubbles can be obtained.

82. BELLOWS ADJUSTMENT - Determine the temperature of the oil and turn the bellows thumb nut (according to the following table) from the position where it just touches the bellows housing with the bellows fully released. If necessary add enough oil to keep the oil level visible in the filler tube.

Temperature Degrees F.	No. of Turns on Bellows Thumb Nut
50	0
60	1.5
70	3.0
80	4.5
90	6.0
100	7.5

83. Remove the filling funnel with whatever oil it contains, and expand the bellows just enough to drop the oil level to the surface of the oil plug hole. Insert, and tighten the plug being sure that no air bubbles have been trapped. Remove the bellows screw and replace the cap screw in the bellows housing. Wipe off all traces of oil from the entire casing, using carbon tetrachloride. Replace the end cap cover.

84. IMPORTANT - It is highly important that the DX tube unit be thoroughly grounded. Unless this is heeded, the unit is a potential source of danger to the patient and the operator, especially hazardous because it induces a false sense of security. The casing must make good contact to the tube stand, through the three screws which fasten against the base lip of the casing. The tube stand in turn must be permanently connected to a good electrical ground.

85. The ground connection from the high-voltage transformer must be fastened to the same ground and as close as possible to the ground lead from the tube stand or side rail unit. A cold water pipe carefully cleaned at the surface of contact is recommended as safe. Do not ground to a gas pipe or heating radiator.

INSTRUCTIONS FOR CHANGING THE X-RAY TUBE IN THE GENERAL ELECTRIC DX CASING - The following material is furnished with the replacement x-ray tube: one set of gaskets, one gallon XPT oil, Cat. A8004B and a small quantity of Sinclair Opaline

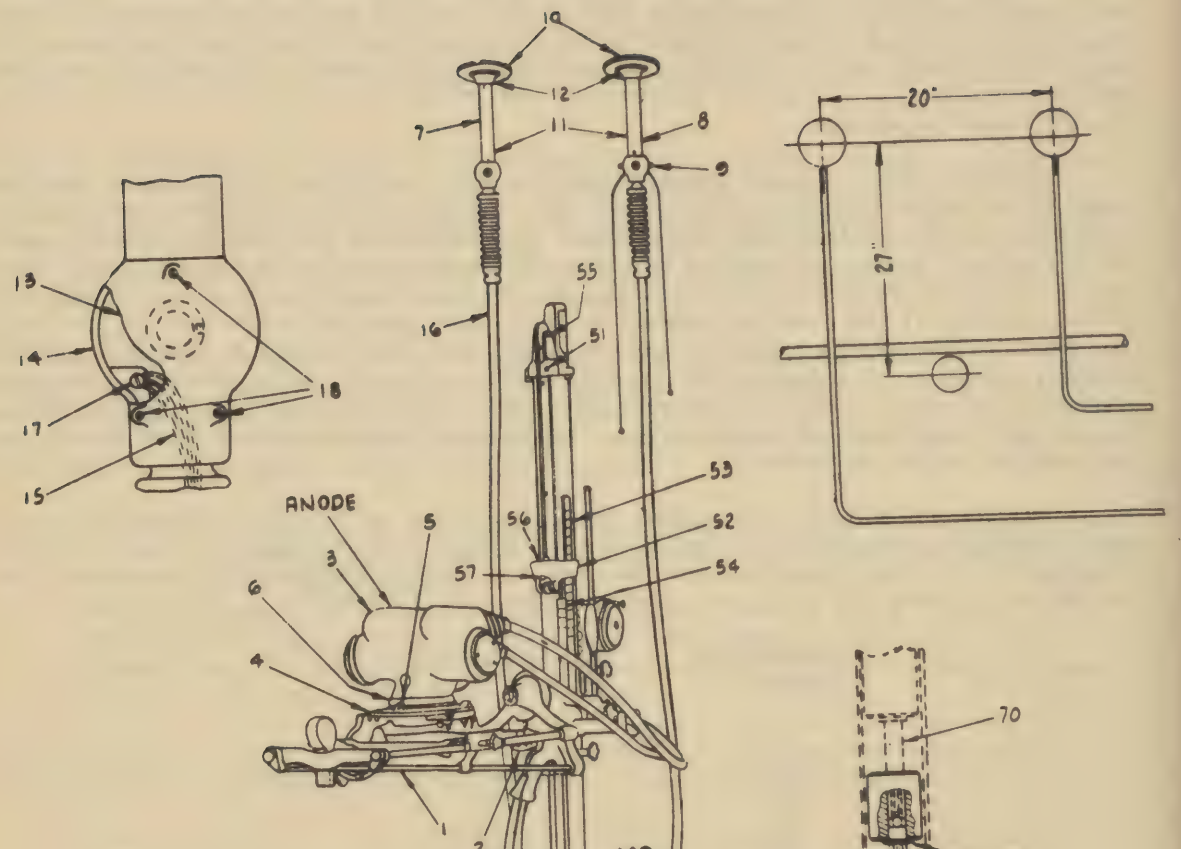


Illustration 1

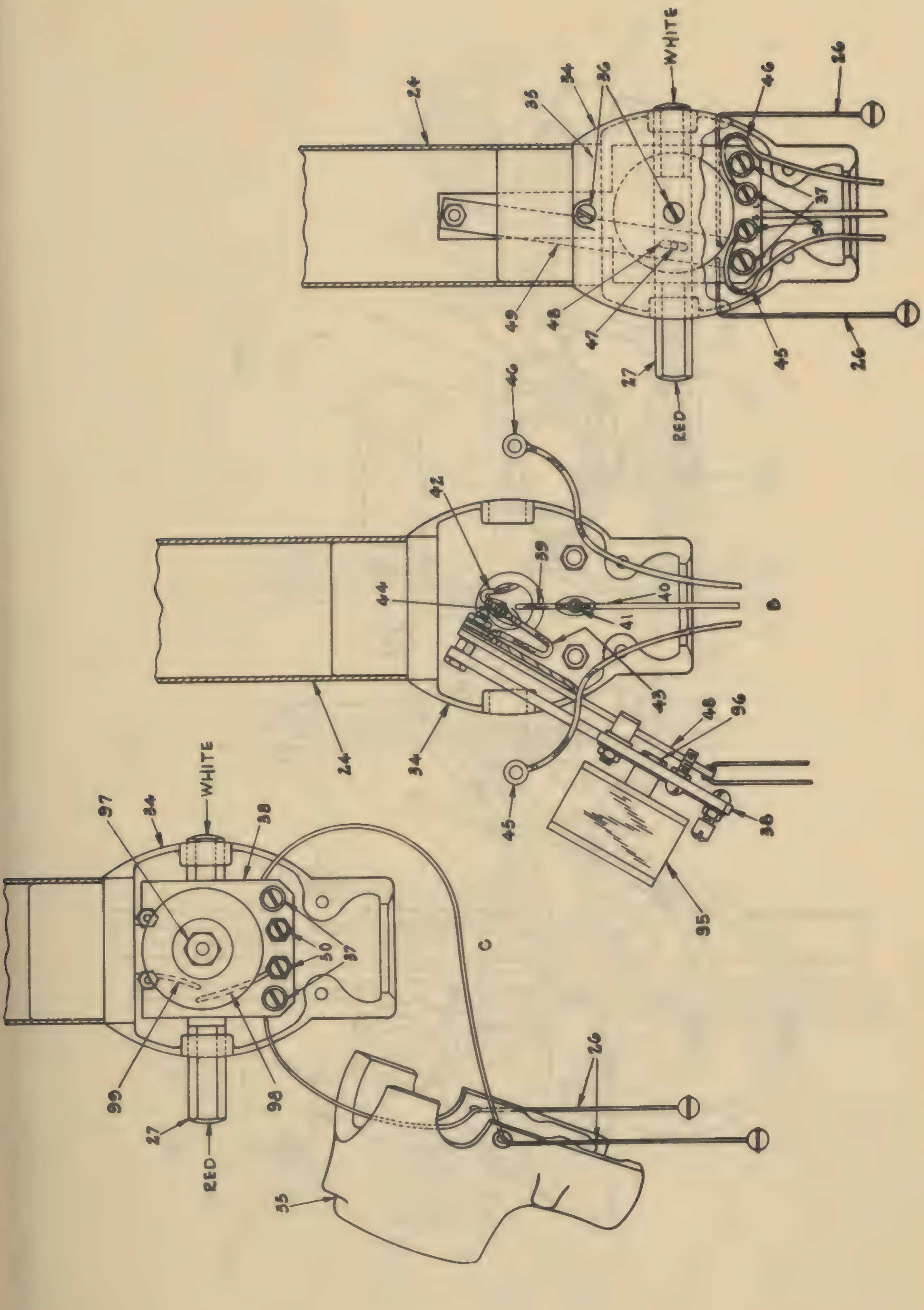


Illustration 2

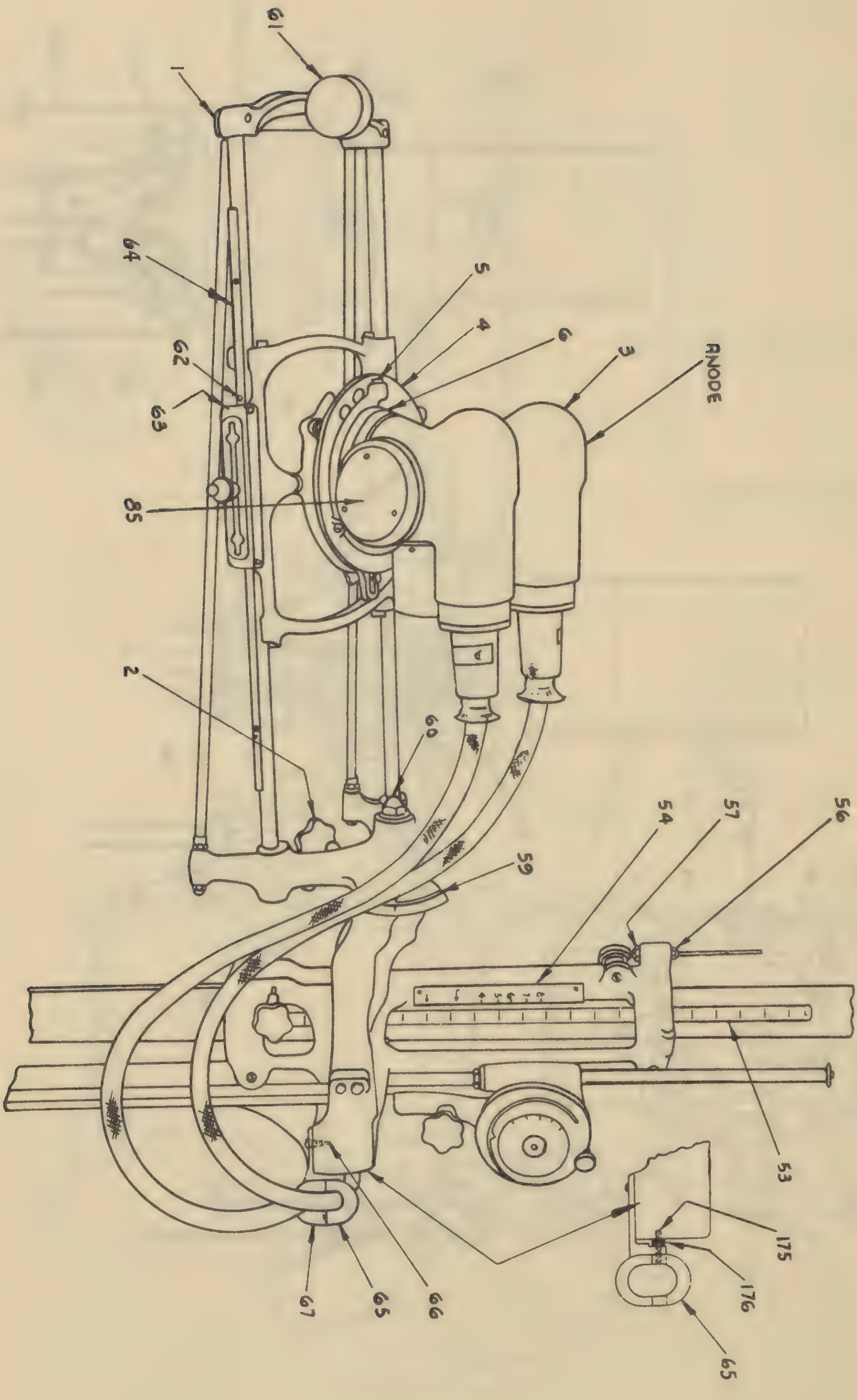


Illustration 3

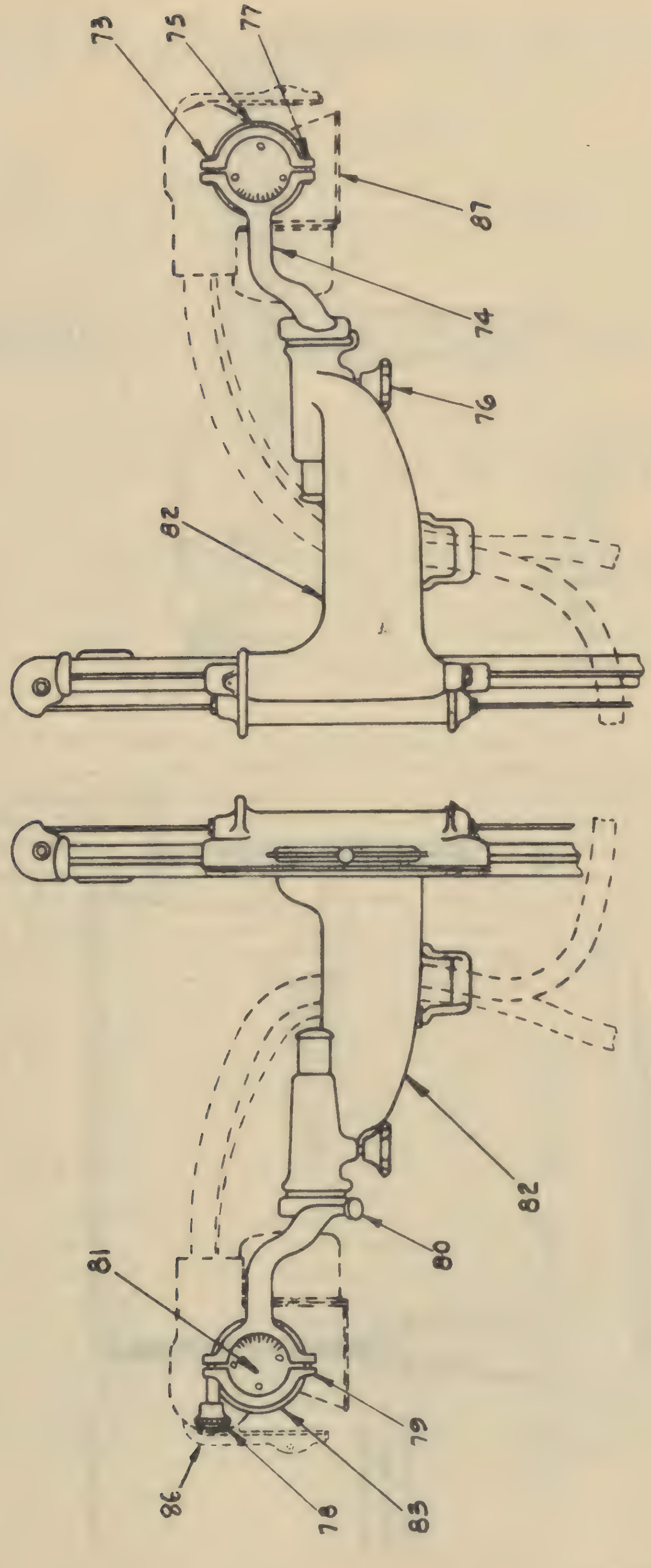


Illustration 4

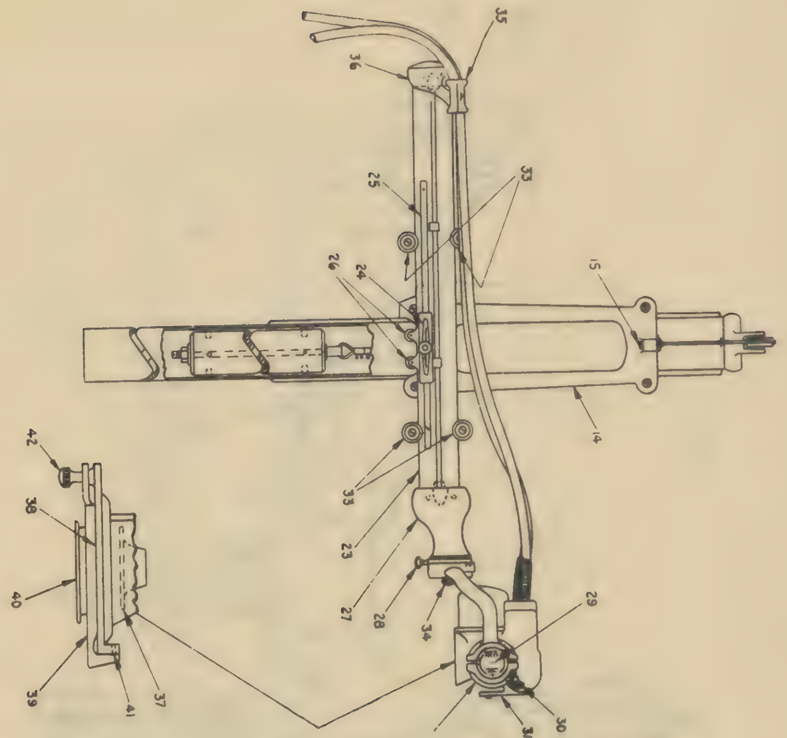
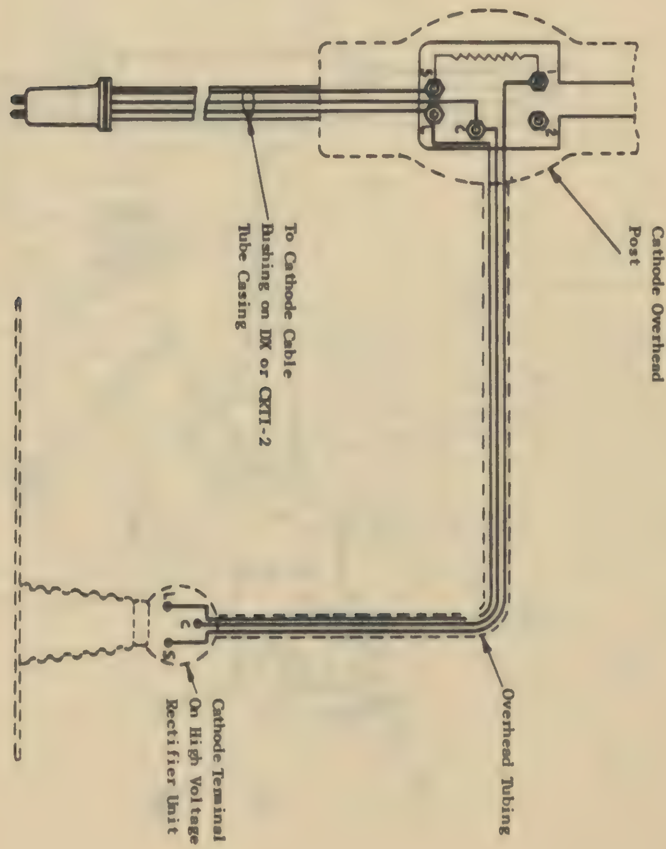


Illustration 4A



CONNECTIONS TO CATHODE OVERHEAD SUPPORT
WHEN A REMOTE FILAMENT SELECTOR IS USED

Illustration 5

Universal Grease. In addition the following material originally furnished with the shockproof casing is required: one glass oil filler tube and one bellows compression screw.

REMOVAL OF TUBE

1. EXTEND BELLOWS - (a) Remove the bellows housing cap screw. (b) Insert the bellows compression screw, threading it in as far as it will go. (c) Turn the thumb nut until it just touches the bellows housing. (d) Extend the bellows by turning the thumb nut one or two turns.

2. DRAIN OIL - (a) Position casing vertically, cathode end up. (b) Remove end covers. (c) Remove cathode and anode oil plugs. (d) Allow to drain several minutes and replace anode oil plug.

3. REMOVE CATHODE CASING-CAP - (a) Remove the six screws holding cathode casing cap in place. (b) Lift off the cap; if necessary insert a knife or thin screwdriver between the two castings to pry them apart. The gasket will be replaced, but use care not to damage the metal seal surfaces.

4. REMOVE TUBE - (a) Remove the large and small screws securing large and small filament leads respectively. (b) Remove screw holding cathode end support to cathode bushing casting. (c) Remove cathode end support and tube by lifting straight out of the casing. (d) Remove cathode end support from tube by unscrewing fastening screws. (e) Place all parts in a clean place, secure from contamination by dirt or moisture.

5. INSTALL NEW TUBE - (a) Wipe the replacement tube with a clean, dry, lint-free rag; if necessary, carbon tetrachloride may be used for cleaning it. Do not use water. (b) Fasten cathode end support to tube so that the seal-off and window are on the opposite side from the support. Leave screw slightly loose so that the tube can align itself by the slot in the radiator. (c) With casing still in a vertical position, cathode up, insert tube in casing, being sure that the anode support engages in the radiator slot. (d) Now engage pilot holes in cathode end support with the pins on the cathode bushing casting. Insert and tighten screw locking cathode end support to cathode bushing casting. Tighten screw fastening tube to cathode end support and the tube will be locked in place.

6. CONNECT FILAMENT LEADS - (a) Connect the lead on the tube having a large cord tip to lead on bushing having a large cord tip. (b) Fasten the cathode end support using large screw. (c) Likewise connect lead on tube having small cord tip to bushing lead having small cord tip and fasten with small screw. The two filament screws are different in size so that it is impossible to get the lead interchanged. Hence, do not force a screw to fit if it is tight, but interchange leads or screws.

7. REPLACE OIL - (a) With casing still in a vertical position and cathode cap off, pour in enough oil to fill the casing about three-quarters full. (b) Agitate the oil for five minutes by shaking and angulating the tube casing. Also work the bellows screw in and out in order to flush that portion of the assembly. (c) Drain out the flushing oil. (d) Fill the casing about three-quarters full with oil (Cat. A8004B), pouring it directly into the casing from the oil can. (e) Turn the casing to lower the open end as far as the oil level will permit without allowing air to enter bellows with bellows in a downward position. Work the bellows screw in and out to expel the air from the bellows; at least five minutes should be spent in this procedure, even if it appears that all air has been excluded before this.

8. CLOSE THE CASING AND REMOVE AIR - (a) With the bellows screw backed out approximately 12 turns, add sufficient oil to bring the level to 1/8 inch from the top of the opening. (b) Remove all portions of the old gasket from the casing and the cap, and clean both seal surfaces, using a rag moistened with carbon tetrachloride. (c) Apply a thin coating of Sinclair Opaline Universal grease to the two metal surfaces and to both sides of a new gasket, working the grease into a thin film and leaving no excess. (d) Apply the gasket, install the cap, and screw down tightly. The proper procedure in tightening is to turn all screws down until they just touch the cap, then take up on each screw only a fraction of a turn at a time until all screws are tight. (e) Remove the plug in the cap and insert the glass oil filler tube. (f) Back off the bellows thumb nut until oil appears in the glass tube at approximately half its depth. If oil does not appear in the filler tube, add sufficient oil to bring the level to the height required. (g) Angulate and shake the casing as much as possible without spilling oil, frequently returning the casing to the vertical position to allow the escape of air. Also, work the bellows screw in and out repeatedly to assist in the process of removing air. This operation is complete when no further air bubbles can be obtained.

When no further air bubbles can be obtained with the cathode end up, the casing should be turned over and the air removing process repeated with the anode end up. Before turning the casing over, extend the bellows until the oil level can just be seen in the oil filler tube. Remove the oil filler tube and insert and tighten the oil plug. Turn the casing over and remove the anode oil plug. Insert the oil filler tube, release bellows, and repeat air removing process. This operation is complete when no further air bubbles can be obtained.

9. ADJUST OIL VOLUME AND SEAL THE CASING - (a) Determine the temperature of the oil and turn the bellows thumb nut (according to the following table) from the position where it just touches the bellows housing with the bellows fully released. If necessary add enough oil to keep oil level visible in the filler tube.

Temperature Degrees F	Number of Turns on Thumb Nut
50	0
60	1.5
70	3.0
80	4.5
90	6.0
100	7.5

(b) Remove the filling funnel with whatever oil it contains, and extend bellows just enough to drop the oil level to the surface of the oil plug hole. (c) Insert and tighten plug, being sure that no air bubbles have been trapped. (d) Remove the bellows-screw and replace the cap screw in the bellows housing. (e) Wipe off all traces of oil from entire casing (carbon tetrachloride may be used for this purpose). (f) Replace the end-cap cover.

10. FINAL TEST - (a) If used on a full-wave or half-wave two kenotron rectified circuit, operate the tube at 100 kv.p. 2 ma. for 10 minutes; if used on a self-rectified circuit operate at 90 kv.p. inverse, 2 ma. for 10 minutes. If there is no sound, as of sparking, the work may be considered as completed; sparking during operation indicates the presence of air which should be removed as in step number eight (8) in the above procedure.

The above instructions for changing the x-ray tube apply when the casing is mounted on a stand so that it is supported by the x-ray cone. When the casing is supported from the end-caps, as is the case with the R-39 Unit a slightly different procedure must be followed. In this case the individual steps are the same as before.

The following procedure is recommended:

1. Remove high-voltage cables by unplugging at casing.
2. Remove the nameplates on both end-caps.
3. Drain casing as outlined in step 2 in the preceding instructions.
4. Remove casing from supporting yoke and, if convenient, mount so that it is supported by the x-ray cone.
5. Now proceed as outlined in the preceding instructions from step number 3 to step number 9, inclusive.
6. Remount casing on tube stand, *seal the bushings, and operate as described in step number 10. If casing operates without sparking replace the nameplates on both end-caps and the work will be complete.

*To reseal the cable bushings, wipe off the bakelite surfaces of the receptacles and the bushings with a cloth moistened with carbon tetrachloride. After allowing the parts to dry for a few minutes, apply a thin coat of fibre grease to both sides of the gasket and place it over the "plug-in" bushing.

Spread "white petrolatum jelly" liberally and evenly all around the middle two inches of the "plug-in" bushing. Use sufficient petrolatum to completely seal the air space in the bushing for a distance of 1½ to 2 inches along its length. Then slowly insert the bushing into the receptacle being careful not to damage the bakelite parts. Fasten the bushing with the four 1-1/4 inch screws and replace the ornamental covers.

GENERAL ELECTRIC MODEL DX COOLIDGE X-RAY TUBE UNIT

DESCRIPTION - The Model DX Coolidge X-Ray Tube Unit consists of either a double or single-focus tube immersed in oil in a shockproof x-ray protective casing, energized through flexible shockproof cables. Each was designed for a type of diagnostic work where its particular focal spot characteristics are either necessary or desirable. Rapidly repeated exposures are made possible by oil immersion, which permits the use of a short anode with consequent rapid transfer of heat to the surrounding oil, and thence to the large radiating area of the entire casing.

The double-focus tube provides a choice between a small focal spot for work requiring fine detail and a large focal spot for heavier work. The method of selecting the focal spot to be used will depend upon the type of equipment energizing the tube. For equipment not supplied with focal spot selection on the control stand, a switch cord suspended from the overhead system is provided.

Manipulation of this switch cord selects the focal spot to be energized, and operates an indicator in the cathode cable suspension post showing the choice made. When the small focal spot is in the circuit the red end of this indicator projects; the white end projects when the large focal spot is in the circuit. Care should be taken to properly reduce the filament setting before energizing the small focal spot.

The casing is provided with a plug-in shockproof cable connection so that the cables can be disconnected readily. Directly beneath the ornamental covers in the

cable parts are screws that fasten the cable onto the casing. The sockets for these cables are permanently sealed at the factory. Removing the shockproof cables does not require removal of the oil.

The housing below the two cable parts contains a bellows which automatically compensates for expansion and contraction of the oil due to changes in temperature of the casing. A constant pressure is thus maintained inside the casing throughout its temperature range.

FOCAL SPOT SIZES - The Model DX Tube Unit is manufactured in a variety of focal spot combinations. The average projected focal spot sizes of each unit are designated on the nameplate of the casing. For example, the average projected focal spot sizes of the double-focus DX2.0-4.5 tube are 2.0 mm square and 4.5 mm square.

FILAMENT CHARACTERISTICS -	Amperes	Volts
Large (or single) focal	3.5-5.5	3.5-10
Small focal spot	3.5-5.5	3.5-8

MAXIMUM VOLTAGE - Full-wave rectified apparatus - 100 kvp
Half-wave or self-rectified apparatus - 90 kvp inverse

TOTAL FILTRATION - Equivalent to approximately 1/4 mm of Al.

WEIGHT OF CASING ON TUBE STAND - Approximately 20 lbs.

MAXIMUM TEMPERATURE (measured on outside of casing): 127F (75C)

BLOWER FOR CASING - The ratings of the DX Tube Unit are dependent upon the speed at which heat produced during operation can be removed from the tube and casing. This tube unit is rated for a definite duty cycle of fluoroscopy or therapy or a certain number of heat units (k.v.p. x ma s) within a certain period. To permit operation for a greater proportion of the time than normal limits of the tube unit allow, a blower which attaches to the tube casing is available as an optional item. It increases the air flow over the surface of the casing, thus increasing the rate of heat dissipation. Within practical limits and taking into consideration the time needed for positioning of the patient and changing of cassettes, the use of the blower permits continuous operation of the DX tube for fluoroscopy and therapy, and the disregarding of the 250,000 k.v.p. x ma s limitation. This applies only to operation on full or half-wave rectified apparatus.

In self-rectified operation, the duty cycle is limited not only by temperature of the casing but also by shockproof cable consideration. Therefore it is recommended that operation on self-rectified circuits be in accordance with the natural cooling duty cycle. The addition of the blower, however, provides an added factor of safety in operation.

Automatic in operation, the blower does not have to be turned on and off by the operator. When the casing reaches a certain temperature, a thermal switch in the anode cap closes and starts the blower. The blower remains on as long as the temperature of the casing is above this point and automatically turns off when the temperature is sufficiently reduced. It is perfectly normal for the blower to remain on after the control stand has been turned off.

DX TUBE UNIT RATINGS - The use of shockproof, high-voltage cable-fed tubes is made possible by the development of insulation materials sufficiently strong to

permit the use of high-voltage without excessive bulk or loss of flexibility. Such cables necessarily have a maximum voltage rating and, in the case of the Model DX Coolidge X-Ray Tube Unit, this rating is 50 k.v.p. on each cable.

On x-ray generating units employing rectifiers which prevent inverse voltage being applied to either cable, the maximum useful voltage may equal 100 k.v.p., i.e., 50 k.v.p. on each cable.

On half-wave circuits employing a single Kenotron, one cable is subjected to half of the full inverse voltage. The other is protected by the Kenotron against inverse voltage. On such equipment the voltage rating must be limited to a value that will not stress the unprotected cable in excess of 45 k.v.p. on the unloaded or inverse half-cycle.

On self-rectified circuits the maximum inverse voltage must not exceed 90 k.v.p. Most self-rectified x-ray units may be operated from an alternating current supply at 85 k.v.p., 30 ma without exceeding the limiting k.v.p. value on the inverse half-cycle.

SAVE YOUR TUBE - The ductility of the tungsten target increases greatly with slight increases in temperature. Before making a fractional second exposure when the anode is at room temperature, it is recommended that the tube first be energized at 15 ma, 75 k.v.p. for 20 seconds; this will produce approximately 25,000 heat units in the anode. This "warming up" procedure will aid in obtaining maximum anode life.

FILAMENT CONSERVATION - In the interest of tube life the filament should not be energized for long periods of time when exposures are not being made. It is good practice to open the filament switch after each exposure unless the next exposure is to follow immediately.

AVOID TESTING - USE THE CHARTS - Testing, a harmful procedure, is considered a necessary part of the operation of x-ray apparatus because of the many years it has been practiced. Few realize that operation of the tube sufficiently long to permit reading the milliammeter usually imposes several times the duty on the tube that is imposed by the subsequent exposure. Frequently the testing factors exceed the rating of the tube. An unfortunate fact in connection with testing is that the heat generated by the test exposure is often not considered in determining the ability of the tube to accept further operation.

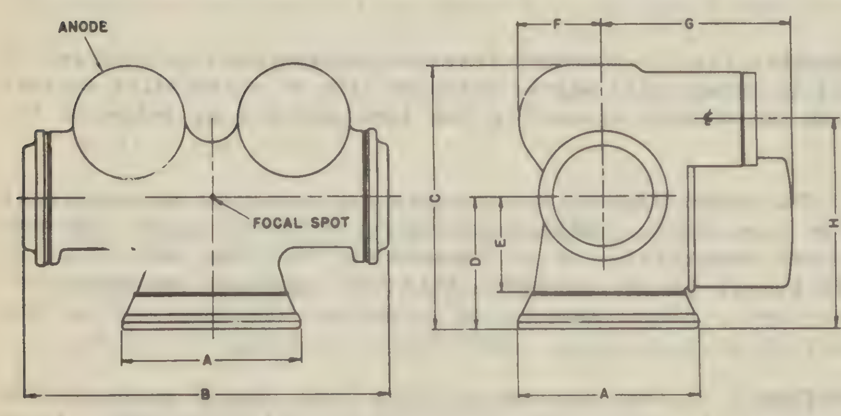
It may be stated conservatively that those who follow this practice of "testing" shorten the life of their tube by as much as fifty percent. Care and proper procedure will reduce this figure to practical insignificance.

Sufficient data and instructions are contained in this manual to permit operating the tube with the dissipation of but a very small percentage of its life in testing procedure. This information is based on the fact that, starting from a definite reference or base value of filament current, a given increase in filament current will produce a definite increase in milliamperage through the tube, as indicated by the charts. This permits pre-setting the filament current for any desired milliamperage and eliminates the necessity of a test reading, thus effecting a saving in tube life.

In order to utilize this method, put into use the simple instructions found on the following page.

USE OF CHARTS - Energy limits and life expectancy are closely associated, the one being inversely related to the other. The rating charts of this tube indicate the maximum energies that are consistent with a reasonable tube life. In all cases, however, a longer life can be obtained by operation at lower energies; in general, keeping below maximum rating chart values of either kilovolts-peak or milliamperage will greatly increase tube life. Our Technical Service Department has carefully compiled the technic charts enclosed with these instructions, with this thought in mind.

DIMENSIONAL DRAWING OF DX CASING



A	5 1/2"	14.0 CM.
B	12"	30.5 CM.
C	7 15/16"	20.2 CM.
D	4"	10.2 CM.
E	3"	7.6 CM.
F	2 1/2"	6.4 CM.
G	5 11/16	14.5 CM.
H	6 1/4"	15.9 CM.

The method of reading the rating charts is simply that of finding the intersecting point of two given or known values on the particular chart applicable to the equipment, at which point the third value is read. For example, to determine the maximum permissible exposure time for given k.v.p. and milliamperage values, follow the horizontal line representing the k.v.p. value to the point where it intersects the diagonal line representing the milliamperage value to be used. The maximum exposure time for which these technic factors may be used is then read on the bottom scale directly below this point of intersection.

FLUOROSCOPIC AND THERAPEUTIC RATINGS - 85 K.V.P., 5MA
*100 K.V.P., 4MA

10 minutes operation in any 20 minute interval. Total operation for a maximum of three hours following which the unit must be allowed to cool to room temperature before repeating the cycle.

85 K.V.P., 3MA

15 minute operation in any 30 minute interval. Total operation for a maximum of four hours following which the unit must be allowed to cool to room temperature before repeating the cycle.

**Note: On self-rectified or one Kenotron half-wave rectified circuits the inverse voltage is not to exceed 90 k.v.p.*

INSTRUCTIONS FOR HIGH-MILLIAMPERAGE TECHNIC - The filament increment chart to the right of the rating charts is an expression of the filament characteristics which permit the pre-determination of the tube milliamperage on the basis of

filament current for various values of kilovoltage. The allowable exposure time values at the higher milliamperages are not sufficiently long to permit the milliammeter to be read without damaging the tube. By setting the filament current to the proper value as determined from the filament increment charts, the desired milliamperage at a given kilovoltage can be obtained without the necessity of making trial exposures before making the radiograph.

In using the filament increment chart, the filament ammeter is the guide to the x-ray tube load and must be read with precision. A grounded-case filament ammeter must be of such design as to accurately indicate the actual filament current. An ammeter in the high-voltage circuit in series with the x-ray tube filament must be installed so as to be unaffected by electrostatic charges or other factors tending to produce erratic readings.

Care must be taken to select the proper chart for either full-wave, half-wave, or self-rectified operation.

PROCEDURE

FULL-WAVE RECTIFIED OPERATION ONLY - Make an exposure on the large focal spot at 50 ma, 80 k.v.p., and note the value of filament current with x-ray voltage applied. This is the base value from which the filament current for any desired value of milliamperage and kilovoltage can be found from the chart.

The filament increment obtained from the filament increment chart is added to this base value; then the filament current is pre-set to this new value.

The filament increment to be added to the base value is determined by following the vertical line representing the k.v.p. to the point of intersection with the diagonal line representing the milliamperage value to be used. The filament increment in amperes corresponding with this point of intersection is then read from the scale on the left of the chart.

HALF-WAVE OR SELF-RECTIFIED OPERATION ONLY - Make an exposure on the large focal spot at 25 ma, 80 k.v.p., and note the value of filament current with x-ray voltage applied. Referring to the filament increment chart for half-wave or self-rectified operation, proceed as for full-wave rectified operation in determining the increment in filament current for other milliamperages and kilovoltages.

IMPORTANT - It is to be emphasized that care and accuracy must be practiced in the initial calibration as well as in pre-setting the ammeter; *the calibration should be checked frequently* because it is subject to variation with time. *A recalibration after each fifty exposures is desirable.*

Special precaution must be taken in using the filament increment chart, if the installation is such that the filament current varies when the x-ray voltage is applied. In some installations, the filament current will decrease with the application of the x-ray load. The filament current should be adjusted until the base value is obtained. The filament current observed when the x-ray load is on is the *base value*. To this base value is added the filament increment obtained from the chart. The filament is then pre-set to this new value, i.e., *the base value plus the increment*. If the filament current increases with application of the x-ray load, the use of the filament increment charts is not recommended.

It is only necessary to read the k.v.p. to the nearest multiple of 5; that is, if the desired k.v.p. is 63, determine the increment from the 65 k.v.p. line; if the

desired k.v.p. is 62, determine the increment from the 60 k.v.p. line.

COOLING DATA - When several exposures are to be made in rapid succession, it may be necessary to take into consideration the heat storage and heat dissipating capacities of the tube. Heat is stored temporarily in the anode and then transferred to the surrounding masses of oil and metal at rates shown by the cooling curves. In considering the amount and rate of heat storage and losses, it is convenient to make use of an arbitrary unit of heat which, on single phase equipment, is equal to the heat produced by one milliampere flowing for one second at a potential of one kilovolt-peak (thus, k.v.p. x ma x sec).

The anode can store safely 250,000 k.v.p.-ma-sec. of heat, after which it must be allowed to cool before further work is attempted. Referring to the cooling curves, it is seen that 30 minutes is required to dissipate 250,000 k.v.p.-ma-sec. If succeeding exposures do not involve the full heat-storage capacity of the tube, it will not be necessary to wait the full 30 minutes.

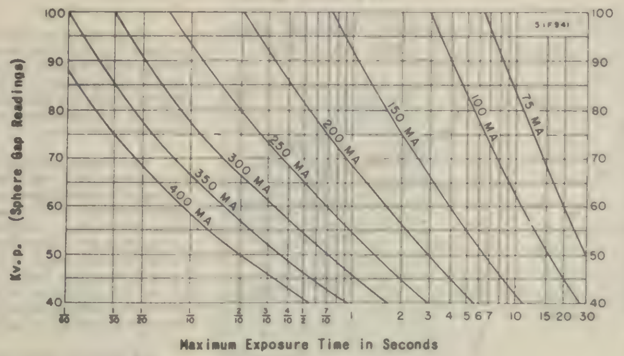
For example, assume that in a busy laboratory, the total heat units of a number of successive exposures is 245,000 and it is necessary to make an exposure which would produce 15,000 heat units. The addition of this amount to that already in the tube would exceed the limitation of the tube by 10,000 heat units. Reference to the cooling curves shows that it will be necessary to wait 1/2 minute before making this exposure.

Consideration of the points discussed in this section has an important bearing on the life of the x-ray tube. Heat input in excess of heat capacity will increase the temperature of the parts with consequent danger to the tube and the possibility of its destruction. In order to prevent such an occurrence, attention must be paid both to the rating charts and to the cooling curves in order to determine the rapidity with which exposures can be made.

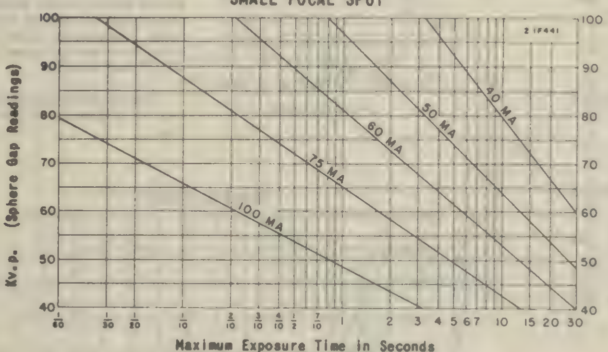
GENERAL ELECTRIC MODEL DX2.2-5.2 X-RAY TUBE

RATINGS WHEN OPERATED ON FULL-WAVE RECTIFIED EQUIPMENT

LARGE FOCAL SPOT



SMALL FOCAL SPOT

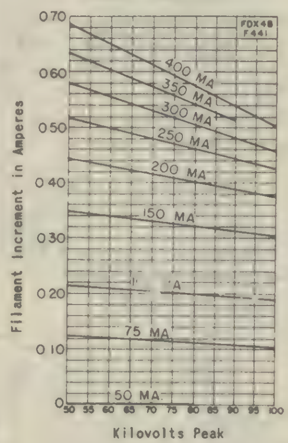


FLUOROSCOPIC AND THERAPEUTIC RATINGS

85 kv.p., 3 ma., 15 minutes operation in any 30 minute interval. Total operation for a maximum of four hours.

85 kv.p., 5 ma., 100 kv.p., 4 ma. 10 minutes operation in any 20 minute interval. Total operation for a maximum of three hours. Continuous operation with a blower mounted on the casing.

FILAMENT INCREMENT CHART LARGE FOCAL SPOT



NOTE

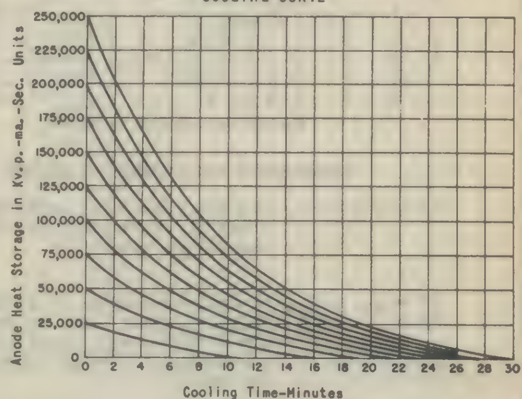
Energy limits and life expectancy are intimately associated in such a way that one is inversely related to the other. The Rating Charts indicate the maximum energies that are consistent with a reasonable tube life.

The Filament Increment Chart is an expression of x-ray tube characteristics that permits the predetermination of milliampere values for various kilovolt values on the basis of filament current. As the filament ammeter is the guide to x-ray tube load, it must be read with precision. A recheck of the filament base value after each fifty exposures is desirable.

The anode can safely store 250,000 heat units (kv.p. x ma.s.) and the Cooling Curves show the rate of heat dissipation from the anode. The use of a blower on the casing increases considerably the rate of heat transfer.

The operation manual contains detailed information on this x-ray tube.

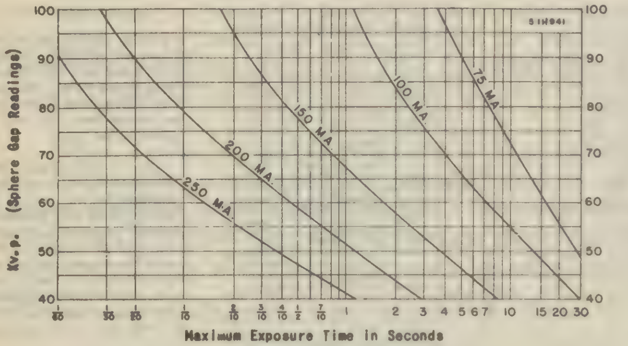
COOLING CURVE



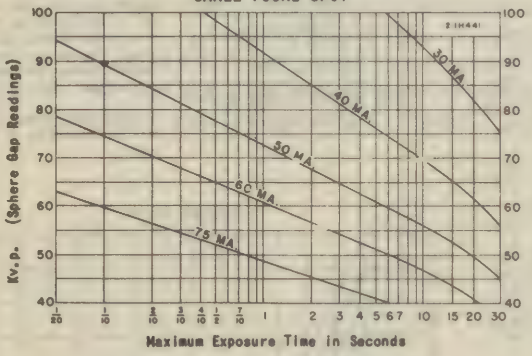
GENERAL ELECTRIC MODEL DX2.2-5.2 X-RAY TUBE

RATINGS WHEN OPERATED ON HALF-WAVE RECTIFIED EQUIPMENT

LARGE FOCAL SPOT



SMALL FOCAL SPOT

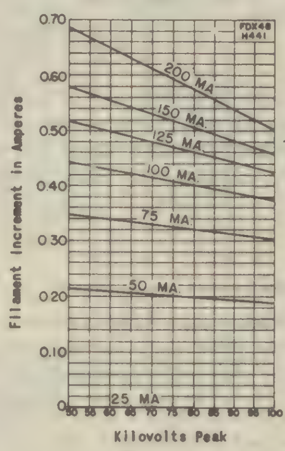


FLUOROSCOPIC AND THERAPEUTIC RATINGS

85 kv.p., 3 ma., 15 minutes operation in any 30 minute interval. Total operation for a maximum of four hours.

85 kv.p., 5 ma., 100 kv.p., 4 ma. 10 minutes operation in any 20 minute interval. Total operation for a maximum of three hours. Continuous operation with a blower mounted on the casing.

FILAMENT INCREMENT CHART LARGE FOCAL SPOT



NOTE

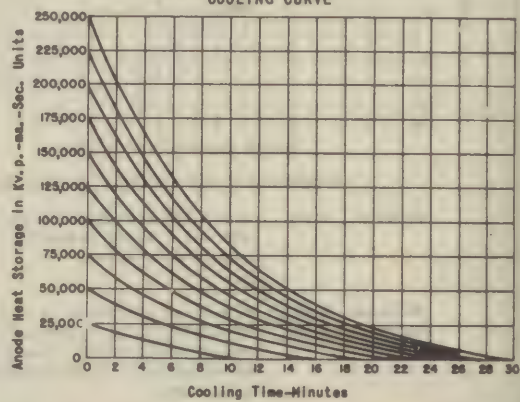
Energy limits and life expectancy are intimately associated in such a way that one is inversely related to the other. The Rating Charts indicate the maximum energies that are consistent with a reasonable tube life.

The Filament Increment Chart is an expression of x-ray tube characteristics that permits the predetermination of milliampere values for various kilovolt values on the basis of filament current. As the filament ammeter is the guide to x-ray tube load, it must be read with precision. A recheck of the filament base value after each fifty exposures is desirable.

The anode can safely store 250,000 heat units (kv.p. x ma.s.) and the Cooling Curves show the rate of heat dissipation from the anode. The use of a blower on the casing increases considerably the rate of heat transfer.

The operation manual contains detailed information on this x-ray tube.

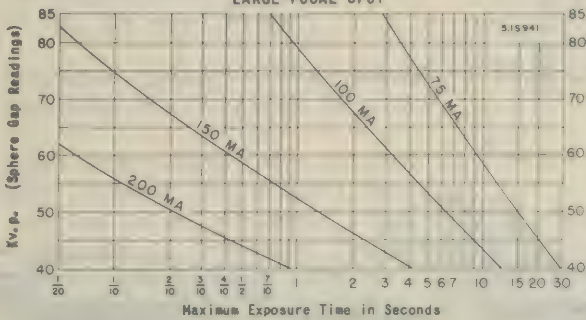
COOLING CURVE



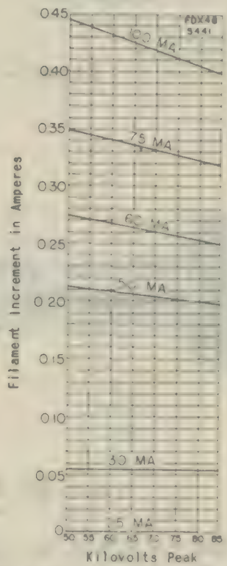
GENERAL ELECTRIC MODEL DX2.2-5.2 X-RAY TUBE

RATINGS WHEN OPERATED ON SELF-RECTIFIED EQUIPMENT

LARGE FOCAL SPOT



FILAMENT INCREMENT CHART
LARGE FOCAL SPOT



NOTE

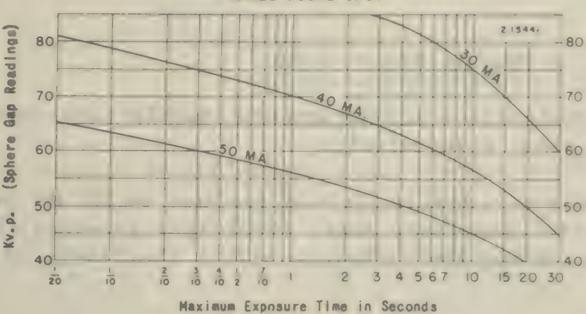
Energy limits and life expectancy are intimately associated in such a way that one is inversely related to the other. The Rating Charts indicate the maximum energies that are consistent with a reasonable tube life.

The Filament Increment Chart is an expression of x-ray tube characteristics that permits the predetermination of milliampere values for various kilovolt values on the basis of filament current. As the filament ammeter is the guide to x-ray tube load, it must be read with precision. A recheck of the filament base value after each fifty exposures is desirable.

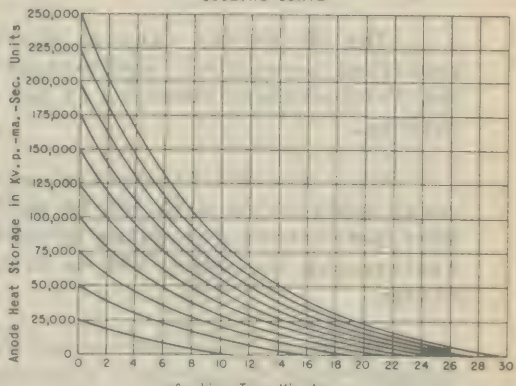
The anode can safely store 250,000 heat units (kv.p. x ma.s.) and the Cooling Curves show the rate of heat dissipation from the anode. The use of a blower on the casing increases considerably the rate of heat transfer.

The operation manual contains detailed information on this x-ray tube.

SMALL FOCAL SPOT



COOLING CURVE



FLUOROSCOPIC AND THERAPEUTIC RATINGS

85 kv.p., 3 ma., 15 minutes operation in any 30 minute interval. Total operation for a maximum of four hours.

85 kv.p., 5 ma., 10 minutes operation in any 20 minute interval. Total operation for a maximum of three hours.

X-RAY TUBES

MACHLETT BULB TYPE X-RAY TUBES

The MR - Series DIAGNOSTIC TUBES

Single-Focus Tube of MR-Series

Type MR-AC plus Double-Focus Tube

The MR Series consists of two single-focus models and one double-focus model, designated as MR-50, MR-100 and MR-AC plus, respectively.

The MR-50 has ratings which make it ideally suited for use on 30 MA self-rectified generators, and because of its relatively small focal spot is widely used for fluoroscopy. However, it may be used for any technique within the limits of its ratings.

The MR-100 finds its most usual application with 100 MA full-wave generators for doing general radiography including 100 Ma techniques.

The MR-AC plus combines an extremely fine focal spot with one suitable for high-milliamperage techniques. With this combination, the complete range of work from the finest detail to heavy duty radiography may be done without changing tubes. A reactor type of protector to protect the fine focus in case an attempt is made to use it for a technique intended for the large

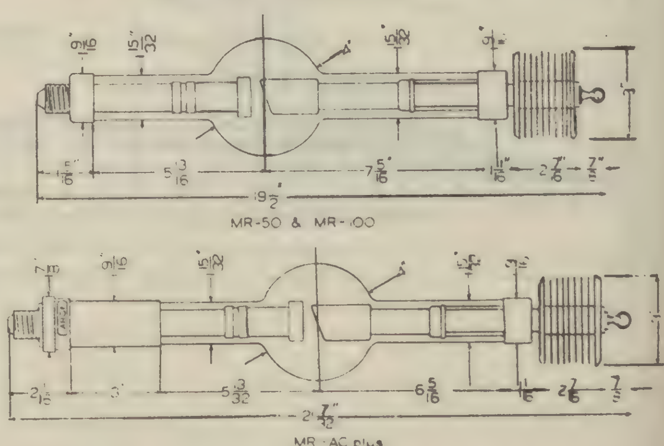


Fig. 1 - Dimensional Data - MR Series

focus, is built into the tube. The focus selecting switch is also an integral part of the tube.

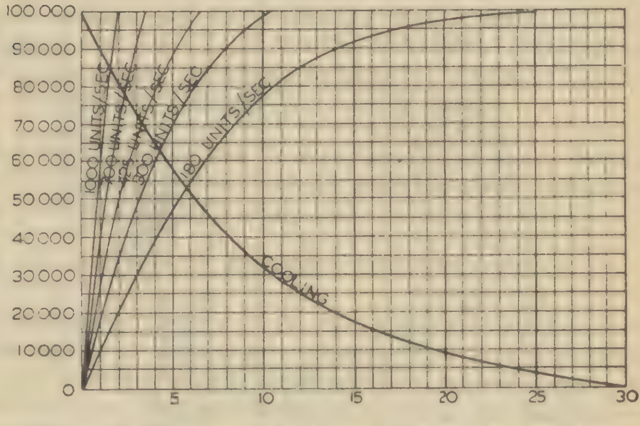
RATINGS AND SPECIFICATIONS

MAXIMUM VOLTAGE RATING - 100 PKV.

MAXIMUM ENERGY RATINGS - As given by the charts below for the various models.

FLUOROSCOPIC RATINGS - 85 PKV, 5 MA, 6½ minutes.

THERMAL CHARACTERISTICS - As indicated by the Chart of Fig. 2.



Thermal Characteristics - MR Series Tubes
Fig. 2

This chart gives the rate of increase in heat content for various average values of power input and the rate of heat dissipation with no input. It can be used to determine the required cooling intervals and their duration, when necessary. The maximum safe heat content is 100,000 units (PKV x MA x Seconds).

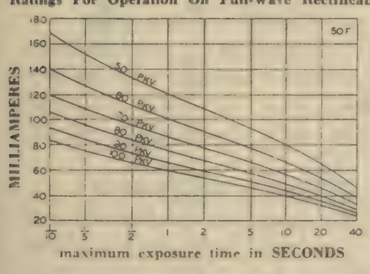
ORDERING INFORMATION: (Manufacturers)

Type	Catalog No.
MR-50	C-402
MR-100	C-403
MR-AC plus	C-401

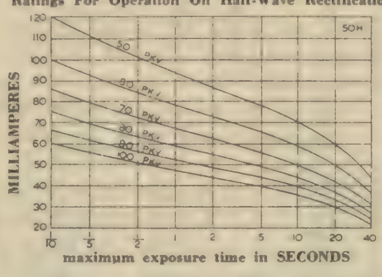
MR-50—Effective Focal Size — 2.6 mm. ■

Filament Characteristics — 3.8 to 4.8 Amps., 4.0 to 5.0 volts.

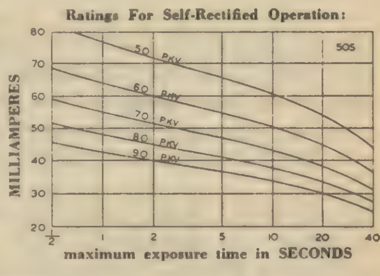
Ratings For Operation On Full-Wave Rectification:



Ratings For Operation On Half-Wave Rectification:



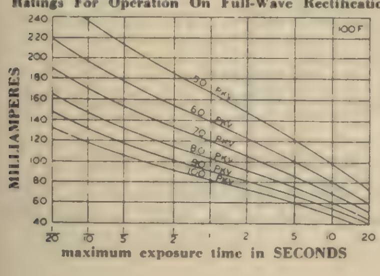
Ratings For Self-Rectified Operation:



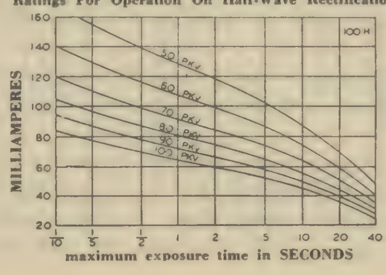
MR-100 — Effective Focal Size — 3.2 mm. ■

Filament Characteristics — 4.0 to 5.0 Amps., 5.0 to 7.0 volts.

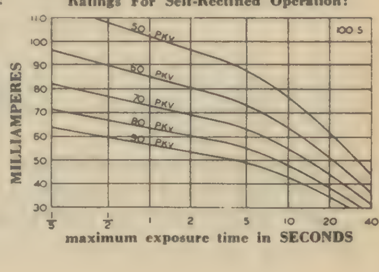
Ratings For Operation On Full-Wave Rectification:



Ratings For Operation On Half-Wave Rectification:



Ratings For Self-Rectified Operation:

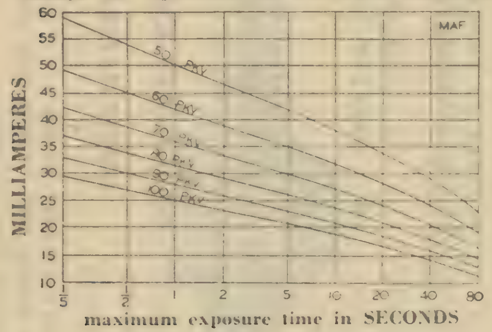


MR-AC plus — Small Focus

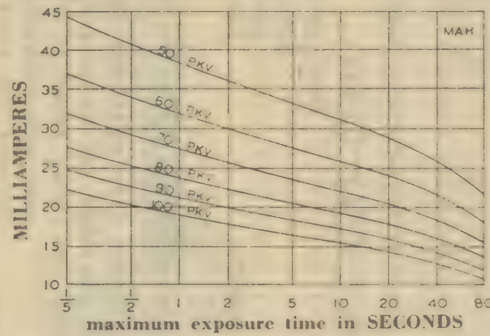
■ Effective Size — 1.5 mm.

Filament Characteristics — 3.5 to 4.5 Amps., 3.0 to 4.0 volts

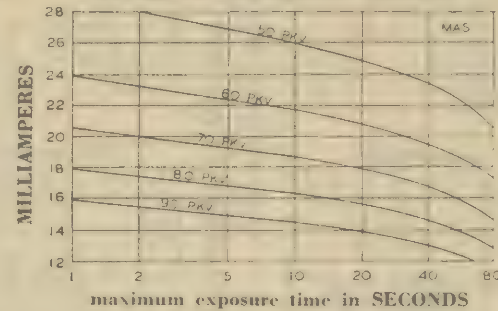
Ratings For Operation On Full-Wave Rectification:



Ratings For Operation On Half-Wave Rectification:



Ratings For Self-Rectified Operation:

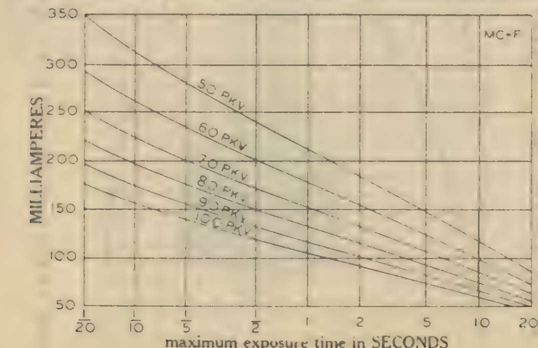


MR-AC plus — Large Focus

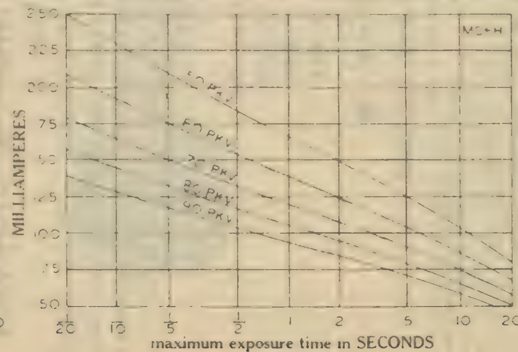
■ Effective Size — 3.8 mm.

Filament Characteristics — 4.0 to 5.0 Amps., 5.0 to 8.0 volts.

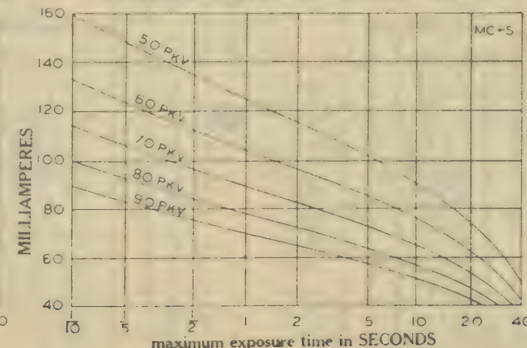
RATINGS FOR OPERATION ON FULL-WAVE RECTIFICATION:



RATINGS FOR OPERATION ON HALF-WAVE RECTIFICATION:



RATINGS FOR SELF-RECTIFIED OPERATION



X-RAY TUBES

INSTRUCTIONS FOR INSTALLATION, OPERATION AND MAINTENANCE OF THE PICKER PX-1B OIL IMMERSED SHOCKPROOF X-RAY TUBE

INSTALLATION - The PX-1B tube is designed to mount directly on the tube carriage of most types of tube stands and tables. It is available with a mounting cone which permits it to be mounted in the same manner as the conventional lead glass bowl on the usual tube stand. This mounting cone is removable, permitting the attachment of any special mounting arrangement desired.

This tube is also available for mounting on the Picker Century units, Picker Comet units and others. In this type of mounting the tube is mounted from the ends, which allows the entire tube head to rotate in its bearings.

The PX-1B tube is supplied with a 1/4mm of Aluminum External Filter.

ELECTRICAL CONNECTIONS - The shockproof cables are the same for either single or double-focus tubes. The anode cable is different, however, from the cathode cable. The cathode cable has three connections -- the smallest or inner-contact is the large-focus filament contact; the center or intermediate contact is the common connection for both small and large-focus filament; the outside or largest connection is the connection for the small-focus filament.

There are no inherent means of limiting the current on the small-focus filament to prevent excessive milliamperage from being impressed on the small sized focal spot of the tube. All Picker X-Ray generators built since 1937 have a milliamperage limiting device in the control to limit this milliamperage on the small sized focal spot of the tube.

It is very important that the bakelite terminations of the cable and the shockproof receptacles in the PX-1B tube housing be thoroughly cleaned before plugging the cables into the tube head. This can be cleaned very easily by wiping with a clean, dry, lintless cloth. A small amount of alcohol or carbon tetrachloride can be used as a cleaning agent if necessary. A small amount of white vaseline or castor oil should be used on the outside of the bakelite terminations to provide the best possible seal between the cable end and the shockproof receptacle.

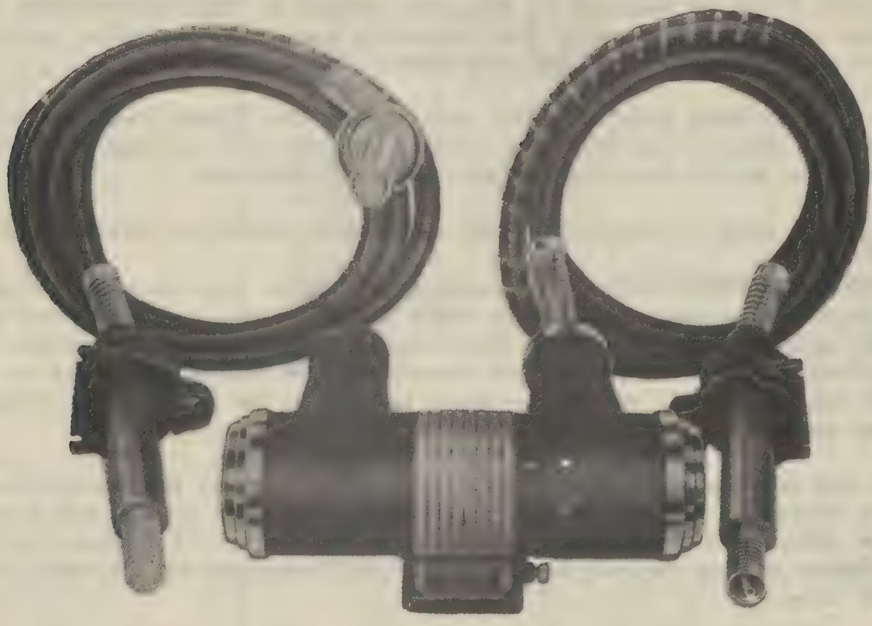
The cables should be plugged into the tube so that the shoulder on the bakelite termination fits against the outer end of the shockproof receptacle on the tube, and the chrome plated spinning on the cable should then be brought up over the cable and screwed onto the tube. Care should be taken so as not to damage the threads, either on the spinning or on the inside of the tube housing.

OPERATION - Before making any exposures on the x-ray tube, carefully check the nameplate ratings of focal spots of the tube against the ratings of the tube as outlined on this sheet. The maximum voltage rating of these tubes is 100 P.Kv. on full-rectified two or four valve or mechanical rectification. The maximum voltage rating on single valve or self-rectified units is 90 P.Kv. The maximum allowable energy load for exposures of any given duration is largely determined by the size of the focal spot. The ratings corresponding to the five different focal spot sizes are given over wide ranges of exposure values on the last page.

The fluoroscopic rating on self-rectified, half-wave or full-wave circuits is ten minutes at 85 P.Kv. and 5 MA, starting with the anode at room temperature.

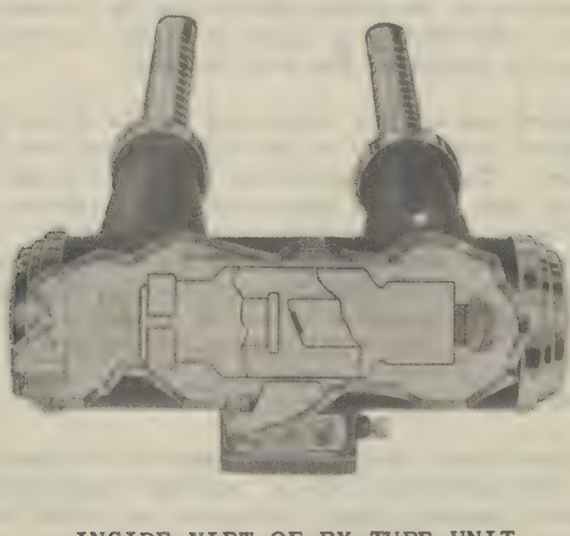
The PX-1B tube head has a heat storage capacity of 250,000 units (P.Kv. times MA times seconds). The radiation rate at maximum temperature is 5,000 units per minute. The unit has a danger signal indicator on either end of the tube. When these indicators protrude beyond the ends of the x-ray tube far enough so that the

red bakelite indicator appears, the tube has reached its maximum temperature and should not be operated any longer.



PX TUBE UNIT

MAINTENANCE - The PX-1B tube housing has been carefully designed to reduce service and maintenance requirements to an absolute minimum. The unit is tested at the factory at voltages far beyond its rating. The PX-1B tube has also been tested under pressure for many days. The only service that should be required is the occasional replacement of a tube unit when the useful life of the tube is over, or the replacement of cables which may break down under certain conditions of use.



INSIDE VIEW OF PX TUBE UNIT

TUBE REPLACEMENTS - The x-ray tube itself is mounted and sealed in the tube unit. This process is carried out at the Factory to insure the conditions necessary for proper operation. When tube failure occurs, a replacement of the entire PX-1B tube housing should be secured.

The replacement procedure consists simply of removing the cables and the mounting arrangements from the whole tube unit and reinstalling the new unit in its place.

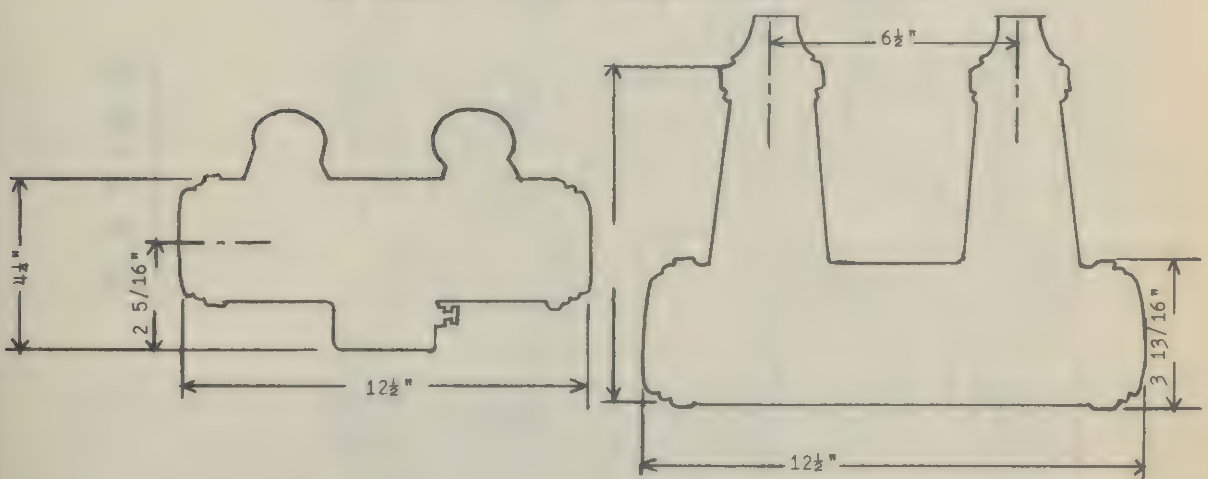
CABLE REPLACEMENT - In case of cable failure, a complete cable fitted with all terminal fittings should be obtained. In ordering the replacement cable, it is necessary to specify whether it is for the anode side or cathode side of the tube. Also specify the type of unit and length of cable necessary.

FLUOROSCOPIC RATINGS - 5 MA times 85 KVP times 10 minutes starting with anode at room temperature.

SPECIFICATIONS

Single-Focus Tubes			Double-Focus Tubes		
Designation	Projected Size	Techniques	Designation	Projected Size	Techniques
"A"	1.5 mm.	10- 20 MA	"AC plus"	1.5 mm.	10- 20 MA
"B"	2.3 mm.	30- 50 MA		3.8 mm.	100-200 MA
"C"	3.2 mm.	60-100 MA	"BC plus"	2.3 mm.	30- 50 MA
"C plus"	3.8 mm.	100-200 MA		3.8 mm.	100-200 MA
"D"	4.2 mm.	100-300 MA	"BD"	2.3 mm.	30- 50 MA
				4.2 mm.	100-300 MA

WEIGHT DATA
Picker "PX" Tube Unit
Net weight - 12 lbs. Shipping weight - 15 lbs.



The schematic drawing above indicates the outside dimensions of the PX tube unit.

CATALOG LISTING

Right angle single-focus tube WITHOUT CABLES. The focal spots available are:

Cat. No.	
9300	"PX" tube with "A" Focal Spot
9301	"PX" tube with "B" Focal Spot
9302	"PX" tube with "C" Focal Spot
9303	"PX" tube with "C+" Focal Spot
9304	"PX" tube with "D" Focal Spot

Right angle double-focus tube WITHOUT CABLES. The focal spots available are:

Cat. No.	
9305	"PX" tube with "AC " Focal Spots
9306	"PX" tube with "BC " Focal Spots
9307	"PX" tube with "BD" Focal Spots

STANDARD CABLE LENGTH: 8 FEET

Any desired cable length will be furnished at extra charge.

CABLES

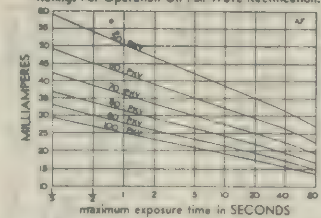
Cat. No.	
9308	Cable for single-focus "PX" tube
9309	Anode cable for double-focus "PX" tube
9310	Cathode cable for double-focus "PX" tube

Specify type of equipment with which cables are to be used. Example: "Comet", "Century", "Series 200", etc.

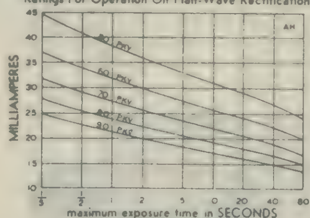
RATING CHARTS FOR PX-1B TUBES

"A" FOCAL SPOT
Effective Size — 1.5 m.m.
Filament Characteristics —
3.5 to 4.5 Amps. 3.0 to 4.0 Volts

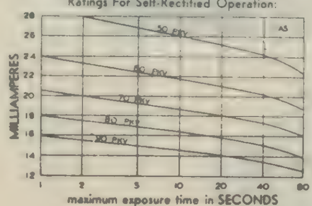
Ratings For Operation On Full-Wave Rectification:



Ratings For Operation On Half-Wave Rectification:

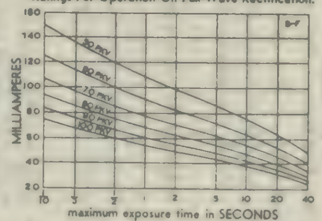


Ratings For Self-Rectified Operation:

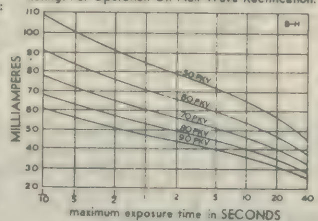


"B" FOCAL SPOT
Effective Size — 2.3 m.m.
Filament Characteristics —
3.7 to 4.7 Amps. 3.5 to 5.0 Volts

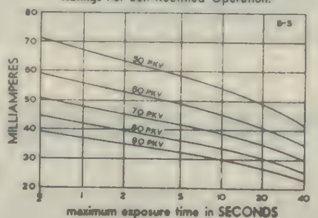
Ratings For Operation On Full-Wave Rectification:



Ratings For Operation On Half-Wave Rectification:

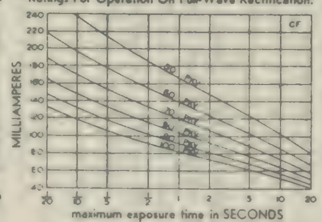


Ratings For Self-Rectified Operation:

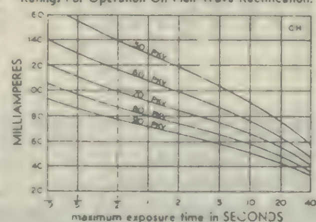


"C" FOCAL SPOT
Effective Size — 3.2 m.m.
Filament Characteristics —
4.0 to 5.0 Amps. 5.0 to 7.0 Volts

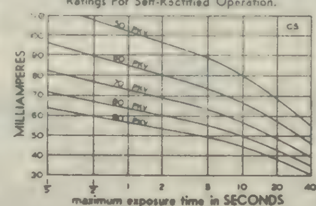
Ratings For Operation On Full-Wave Rectification:



Ratings For Operation On Half-Wave Rectification:

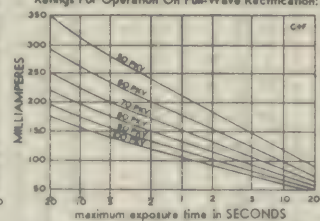


Ratings For Self-Rectified Operation.

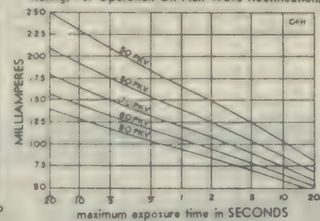


"C PLUS" FOCAL SPOT
Effective Size — 3.8 m.m.
Filament Characteristics —
4.0 to 5.0 Amps. 5.0 to 8.0 Volts

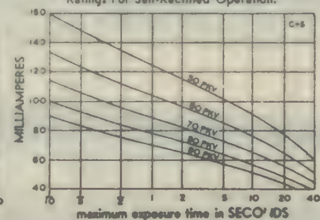
Ratings For Operation On Full-Wave Rectification:



Ratings For Operation On Half-Wave Rectification:

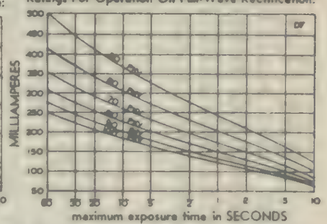


Ratings For Self-Rectified Operation:

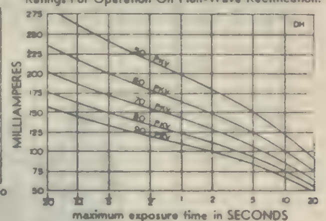


"D" FOCAL SPOT
Effective Size — 4.2 m.m.
Filament Characteristics —
4.0 to 5.2 Amps. 5.5 to 9.0 Volts

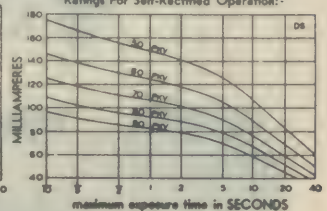
Ratings For Operation On Full-Wave Rectification:

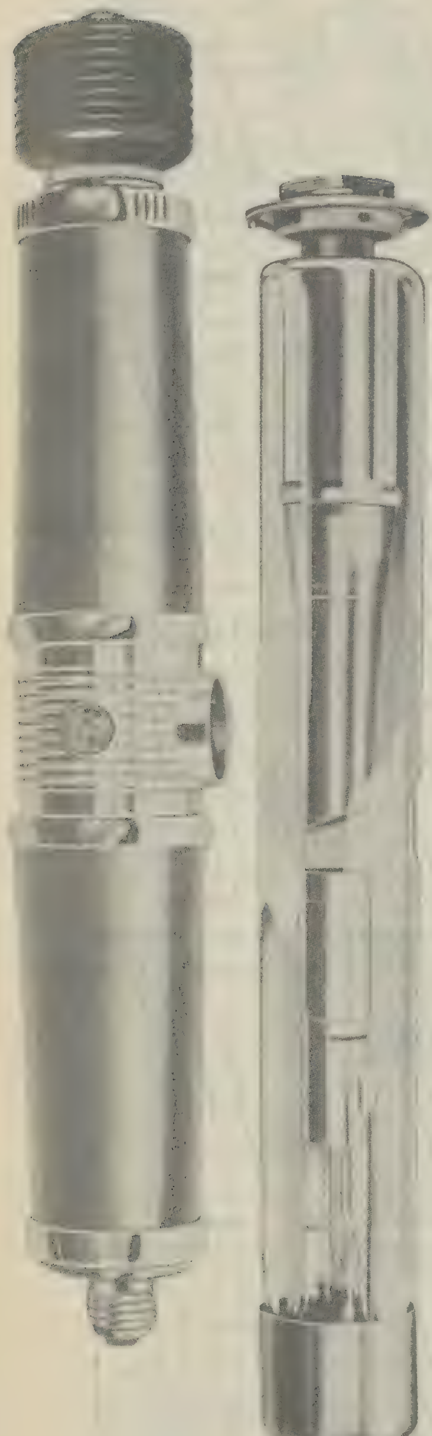


Ratings For Operation On Half-Wave Rectification:



Ratings For Self-Rectified Operation:-





DESCRIPTION - The Model XP Coolidge X-Ray Tube consists of either a double or single-focus tube with an x-ray protective shield. The protective shield, designed as a separate unit, may be used with any of the XP tubes.

Energy limits and life expectancy are inversely related. The rating charts, supplied with this tube, indicate the maximum energies that are consistent with a reasonable tube life. The life of the tube will be greatly increased by operating at lower energies; that is, by keeping below the maximum rating of either kilovolts peak or milliamperes. Our Technical Service Department has compiled carefully the technic chart supplied with this tube.

The double-focus tube provides a choice between a small focal spot for work requiring fine detail and a large focal spot for heavier work. The method of selecting the focal spot to be used will depend upon the type of equipment energizing the tube. For equipment not supplied with focal spot selection on the control stand, a switch can be supplied for mounting on the cathode end of the tube. This switch incorporates a nameplate showing the focal spot that will be energized when the tube is used.

FOCAL SPOT SIZES - The model XP tube is manufactured in a variety of focal spot combinations. The average projected focal spot sizes of each unit are designated on the rating chart that is supplied with the tube.

MAXIMUM VOLTAGE -

Full-wave rectified apparatus
with protective shield . . . . . . 110 kvp

Full-wave rectified apparatus
without protective shield. . . . . 100 kvp

Self-rectified or single kenotron
rectified apparatus. . . . . 85 kvp

SAVE YOUR TUBE

FILAMENT CONSERVATION - In the interest of tube life, the filament should not be energized for long periods of time when exposures are not being made. It is good practice to open the filament switch after each exposure

unless the next exposure is to follow immediately.

AVOID TESTING, USE THE CHART - Testing, a harmful procedure, is considered a necessary part of the operation of x-ray apparatus because of the many years it has been practiced. Few realize that operation of the tube sufficiently long to permit reading the milliamperage usually imposes several times the heating that is imposed while the exposure is made. Frequently, the testing factors exceed the rating of the tube. An unfortunate fact in connection with testing is that the heat generated by the test exposure is often not considered in determining the ability of the tube to accept further operation.

It may be stated conservatively that those who follow this practice of "testing" shorten the life of their tube by as much as fifty per cent. Care and proper procedure will reduce this figure to practical insignificance.

Sufficient data and instructions are contained in this manual to permit operating the tube with the dissipation of but a very small percentage of its life in testing procedure. This information is based on the fact that, starting from a definite reference or *base value* of filament current, a given increase in filament current will produce a definite increase in milliamperage through the tube, as indicated by the chart. This permits pre-setting the filament current for any desired milliamperage and eliminates the necessity of a test reading, thus effecting a saving in tube life. In order to utilize this method, put into use the simple instructions found here.

USE OF RATING CHARTS - Energy limits and life expectancy are closely associated, the one being inversely related to the other. The rating charts of this tube indicate the maximum energies that are consistent with a reasonable tube life. In all cases, however, a longer life can be obtained by operation at lower energies; in general, keeping below maximum rating chart values of either kilovolts-peak or milliamperage will greatly increase tube life. Our Technical Service Department has carefully compiled the technic charts enclosed with these instructions, with this thought in mind.

The method of reading the rating charts is simply that of finding the intersecting point of two given or known values on the particular chart applicable to the equipment, at which point the third value is read. For example, to determine the maximum permissible exposure time for given kvp and milliamperage values, follow the horizontal line representing the kvp value to the point where it intersects the diagonal line representing the milliamperage value to be used. The maximum exposure time for which these technic factors may be used is then read on the bottom scale directly below this point of intersection.

FLUOROSCOPIC AND THERAPY RATINGS

AIR-COOLED RADIATOR - 85 KVP, 5MA 12 minutes operation in
*100 KVP, 4MA any 27 minute interval

85 KVP, 3MA Continuous operation

WATER-COOLED RADIATOR - 85 KVP, 7MA Continuous operation
*100 KVP, 5MA Continuous operation

**Note: On self-rectified or one kenotron half-wave rectified circuits, the kilovoltage is not to exceed 85 kvp.*

INSTRUCTIONS FOR HIGH-MILLIAMPERAGE TECHNIC

The filament increment chart to the right of the rating charts is an expression of the filament characteristics which permit the pre-determination of the tube milliamperage on the basis of filament current for various values of kilovoltage. The allowable exposure time values at the higher milliamperages are not sufficiently long to permit the milliammeter to be read without damaging the tube. By setting the filament current to the proper value as determined from the filament increment charts, the desired milliamperage at a given kilovoltage can be obtained without the necessity of making trial exposures before making the radiograph.

In using the filament increment chart, the filament ammeter is the guide to the x-ray tube load and must be read with precision. A grounded-case filament ammeter must be of such design as to accurately indicate the actual filament current. An ammeter in the high-voltage circuit in series with the x-ray tube filament must be installed so as to be unaffected by electrostatic charges or other factors tending to produce erratic readings.

Care must be taken to select the proper chart for either full-wave, half-wave, or self-rectified operation.

PROCEDURE - FULL-WAVE RECTIFIED OPERATION ONLY

Make an exposure on the large focal spot at 50 ma, 80 kvp, and note the value of filament current with x-ray voltage applied. This is the *base value* from which the filament current for any desired value of milliamperage and kilovoltage can be found from the chart.

The filament increment obtained from the filament increment chart is added to this *base value*; then the filament current is pre-set to this new value.

The filament increment to be added to the *base value* is determined by following the vertical line representing the kvp to the point of intersection with the diagonal line representing the milliamperage value to be used. The filament increment in amperes corresponding with this point of intersection is then read from the scale on the left of the chart.

HALF-WAVE OR SELF-RECTIFIED OPERATION ONLY - Make an exposure on the large focal spot at 25 ma, 80 kvp, and note the value of filament current with x-ray voltage applied. Referring to the filament increment chart for half-wave or self-rectified operation, proceed as for full-wave rectified operation in determining the increment in filament current for other milliamperages and kilovoltages.

IMPORTANT - It is to be emphasized that care and accuracy must be practiced in the initial calibration as well as in pre-setting the ammeter; *the calibration should be checked frequently* because it is subject to variation with time. *A recalibration after each fifty exposures is desirable.*

Special precaution must be taken in using the filament increment chart, if the installation is such that the filament current varies when the x-ray voltage is applied. In some installations, the filament current will decrease with the application of the x-ray load. The filament current should be adjusted until the base value is obtained. The filament current observed when the x-ray load is on is the *base value*. To this *base value* is added the filament increment obtained from the chart. The filament is then pre-set to this new value, i.e., the *base value plus the increment*. If the filament current increases with application of the x-ray load, the use of the filament increment charts is not recommended.

It is only necessary to read the kvp to the nearest multiple of 5; that is, if the desired kvp is 63, determine the increment from the 65 kvp line; if the desired kvp is 62, determine the increment from the 60 kvp line.

COOLING INTERVALS - An exposure may be made whenever the heat still in the tube from previous exposures together with the heat involved in the one which is to be made does not exceed 120,000 kvp -ma -sec.-(kvp x ma x seconds). A minimum of 5 seconds cooling time, however, must be allowed between the rating chart exposures (with the exception of very short stereo exposures). In considering the discussion of cooling intervals it is convenient to make use of an arbitrary unit of heat for both self-rectified circuits (single-phase) kvp x ma x seconds.

Heat stored in the tube due to previous exposures will be lost gradually as shown by the cooling curves on the rating chart. Five minutes is sufficient time for the XP water cooled tube to lose all its stored heat. Fifteen minutes are required by the XP air cooled tube.

DETERMINING COOLING INTERVALS - The method of determining proper cooling intervals for any given series of exposures is quite simple and involves the use of an arbitrary unit of heat which is defined as the heat produced by one kilovolt peak with a tube current of one milliampere flowing through the tube for one second. Thus, in these units, the heat stored in the tube on an exposure of 75 kvp, 80 ma and 3 seconds would be 18,000 kvp-ma-seconds; six such exposures could be made without rest intervals other than the minimum 5 second interval between exposures.

Cooling intervals become necessary when the total heat involved in a series of exposures exceeds the heat capacity of the tube, that is, 120,000 kvp -ma -sec. In a series of ten exposures the first six produce 108,000 kvp -ma -sec.; before the last four exposures may be made the tube must be allowed to cool until the heat produced by them will not increase the heat stored in the anode to more than 120,000 kvp -ma -sec. It is not necessary to allow the tube to cool until all of this stored heat is dissipated; the tube must be allowed to cool until the heat storage is reduced to a point where the remaining four exposures will not increase the total to more than 120,000 units.

Consideration of the points discussed in this section has an important bearing on the life of the x-ray tube. Heat input in excess of heat capacity will increase the temperature of the parts with consequent danger to the tube and the possibility of its destruction. In order to prevent such an occurrence, attention must be paid both to the rating charts and to the cooling curves in order to determine the rapidity with which exposures can be made.

X-RAY TUBE TROUBLES

All radiographic tubes are furnished with two types of rating charts showing:

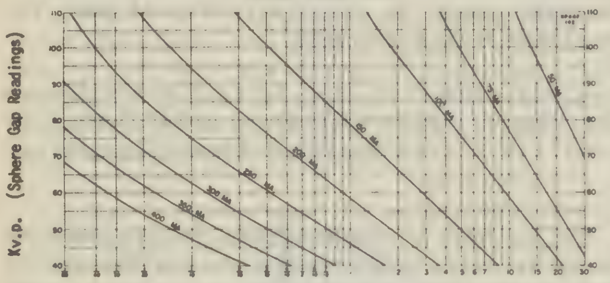
1. The Electrical Characteristics:
   a. The maximum load energies are shown in terms of kilovolt-peak, milliamperage and time in seconds.
   b. There are three of these electrical characteristic charts as follows:

      (1) Full-Wave Rectification
      (2) Half-Wave Rectification
      (single valve unit)
      (3) Self-Rectification

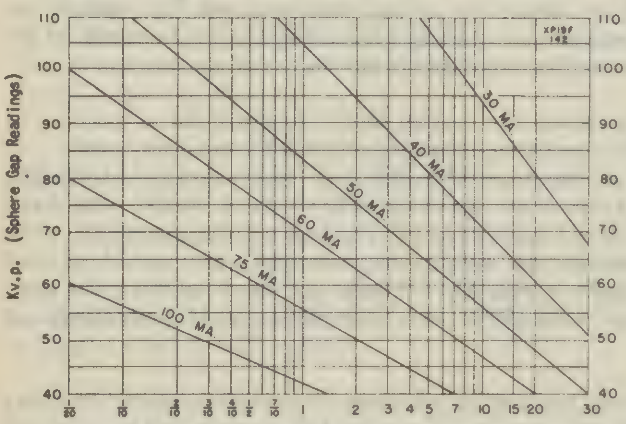
GENERAL ELECTRIC MODEL XP2.0-4.5 X-RAY TUBE

RATINGS WHEN OPERATED ON FULL-WAVE RECTIFIED EQUIPMENT

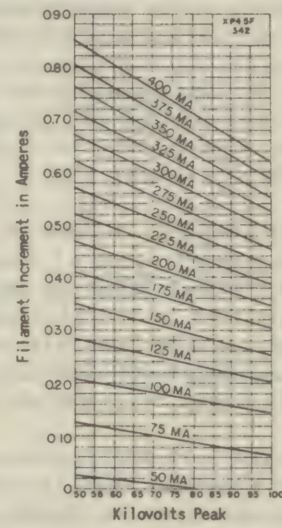
LARGE FOCAL SPOT



SMALL FOCAL SPOT



FILAMENT INCREMENT CHART
LARGE FOCAL SPOT



NOTE

Energy limits and life expectancy are intimately associated in such a way that one is inversely related to the other. The Rating Charts indicate the maximum energies that are consistent with a reasonable tube life.

The Filament Increment Chart is an expression of x-ray tube characteristics that permits the predetermination of milliampere values for various kilovolt values on the basis of filament current. As the filament ammeter is the guide to x-ray tube load, it must be read with precision. A recheck of the filament base value after each fifty exposures is desirable.

The anode can safely store 120,000 heat units (kv.p. x ma.s.) and the Cooling Curves show the rate of heat dissipation from the anode.

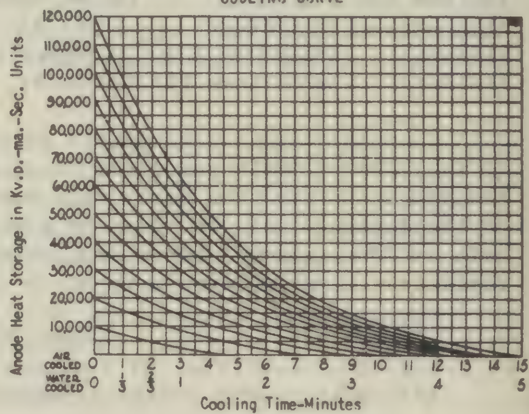
The operation manual contains detailed information on this x-ray tube.

Filament Characteristics
3.5-5.5 amperes - 3.5-8.0 volts.

FLUOROSCOPIC AND THERAPEUTIC RATINGS

Air Cooled	85 kv.p., 5 ma., 12 minutes operation in any 27 minute interval.
	110 kv.p., 4 ma., 12 minutes operation in any 27 minute interval.
	85 kv.p., 3 ma., continuous.
Water Cooled	85 kv.p., 7 ma., continuous.
	110 kv.p., 5 ma., continuous.

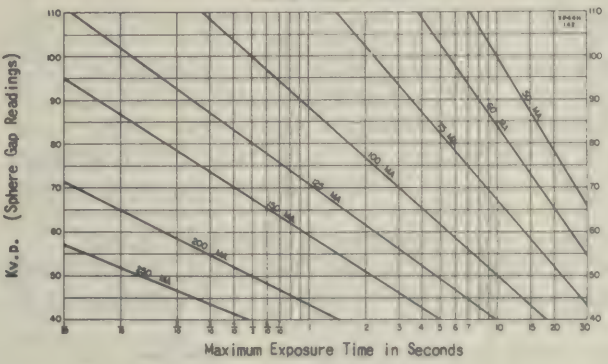
COOLING CURVE



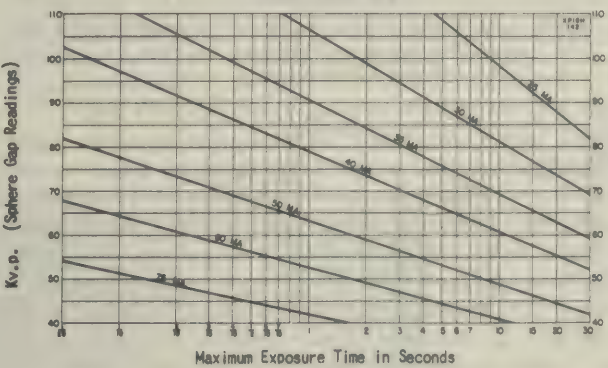
GENERAL ELECTRIC MODEL XP2.0-4.5 X-RAY TUBE

RATINGS WHEN OPERATED ON HALF-WAVE RECTIFIED EQUIPMENT

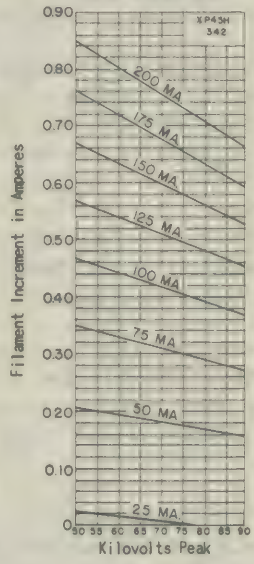
LARGE FOCAL SPOT



SMALL FOCAL SPOT



FILAMENT INCREMENT CHART
LARGE FOCAL SPOT



NOTE

Energy limits and life expectancy are intimately associated in such a way that one is inversely related to the other. The Rating Charts indicate the maximum energies that are consistent with a reasonable tube life.

The Filament Increment Chart is an expression of x-ray tube characteristics that permits the predetermination of milliampere values for various kilovolt values on the basis of filament current. As the filament ammeter is the guide to x-ray tube load, it must be read with precision. A recheck of the filament base value after each fifty exposures is desirable.

The anode can safely store 120,000 heat units (kv.p. x ma.s.) and the Cooling Curves show the rate of heat dissipation from the anode.

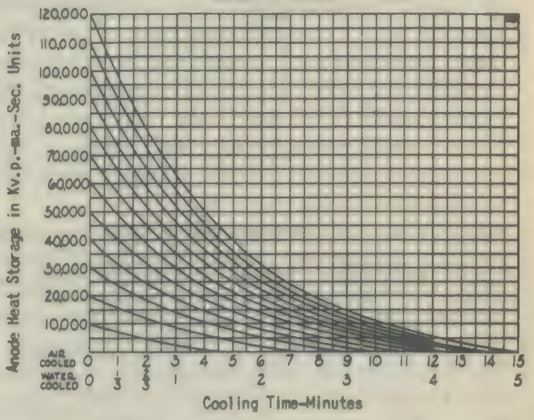
The operation manual contains detailed information on this x-ray tube.

Filament Characteristics
3.5-5.5 amperes - 3.5-8.0 volts.

FLUOROSCOPIC AND THERAPEUTIC RATINGS

Air Cooled	85 kv.p., 5 ma., 12 minutes operation in any 27 minute interval.
	110 kv.p., 4 ma., 12 minutes operation in any 27 minute interval.
	85 kv.p., 3 ma., continuous.
Water Cooled	85 kv.p., 7 ma., continuous.
	110 kv.p., 5 ma., continuous.

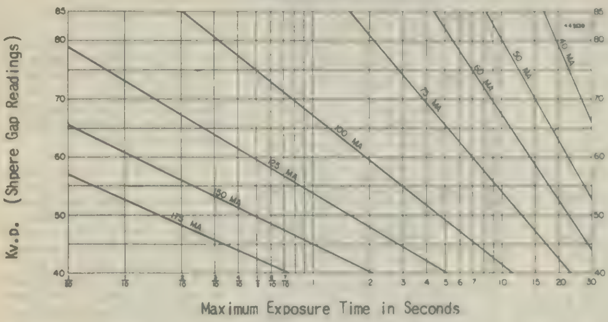
COOLING CURVE



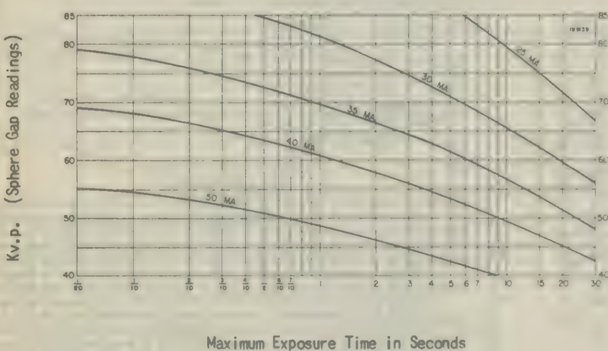
GENERAL ELECTRIC MODEL XP 2.0-4.5 X-RAY TUBE

RATINGS WHEN OPERATED ON SELF-RECTIFIED EQUIPMENT

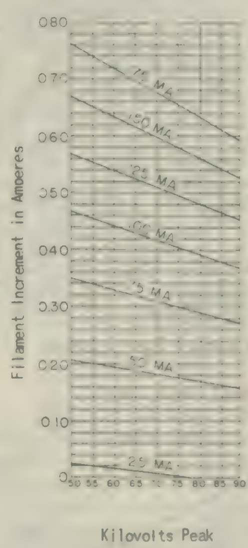
LARGE FOCAL SPOT



SMALL FOCAL SPOT



FILAMENT INCREMENT CHART
LARGE FOCAL SPOT



NOTE

Energy limits and life expectancy are intimately associated in such a way that one is inversely related to the other. The Rating Charts indicate the maximum energies that are consistent with a reasonable tube life.

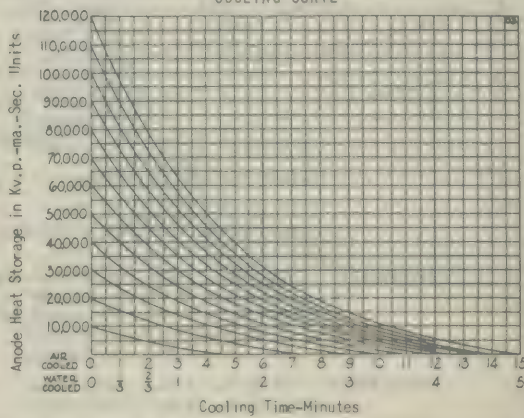
The Filament Increment Chart is an expression of x-ray tube characteristics that permits the predetermination of milliampere values for various kilovolt values on the basis of filament current. As the filament ammeter is the guide to x-ray tube load, it must be read with precision. A recheck of the filament base value after each fifty exposures is desirable.

The anode can safely store 120,000 heat units (kv.p. x ma.s.) and the Cooling Curves show the rate of heat dissipation from the anode.

The operation manual contains detailed information on this x-ray tube.

Filament Characteristics
3.5-5.5 amperes - 3.5-8.0 volts.

COOLING CURVE



FLUOROSCOPIC AND THERAPEUTIC RATINGS

Air Cooled	85 kv.p., 5 ma., 12 minutes operation in any 27 minute interval. 85 kv.p., 3 ma., continuous.
Water Cooled	85 kv.p., 7 ma., continuous.

2. Thermal Characteristics:

   a. Heat storage capacity - Expressed in arbitrary units described as "Heat Units" (the product of the peak kilovolt times the milliamperage times the time in seconds (K.V.P. x MA. x sec.).
   b. Cooling characteristics - Usually shown in graph - the number of heat units lost in any period of time following an exposure.

The loading characteristics for the maximum exposure time are essentially controlled by the size of the focal spot. The smaller the focal spot size, the lower the maximum energy limits. Maximum energy limits are also controlled to some extent by the thickness of the tungsten button used for the target. The shape and the angle of the focus also play a part in load capacity consideration.

If an X-ray tube is operated at its full capacity on occasional exposure there is, of course, danger of actually exceeding this maximum load because of errors in the timing mechanism, the meter, or errors in the calibration of the unit. For optimum life, therefore, it is better to stay within the ratings of the x-ray tube rather than to exceed them.

The rating charts furnished with each tube should be strictly adhered to. For conservative operation and optimum life of the tube, it is recommended that the tube be operated at 80 to 90% of the maximum value shown on each chart.

In making a series of radiographic exposures it is not only important to know the maximum energy that can be used safely on individual exposures but also the frequency with which they can be repeated. Cooling curves have been calculated for this purpose. These curves show the role of heat dissipation from the anode with various initial values of heat storage.

The thermal ratings are based on the heat dissipation of the x-ray tube and the heat storage capacity of the tube. For exposure times which are very short, such as those used in high-milliamperage radiography, the size of the focal spot limits the rating of the tube. Practically all stationary anode x-ray tubes have tungsten anodes set in copper backing. Tungsten has a definite melting point. Therefore, all radiographic tubes having the same size focal spot should have the same milliamperage rating, providing the various companies operate on the same safety factor. If a tube of one manufacturer is rated slightly higher for the same size focal spot than that of another manufacturer, it merely means that that particular company is allowing less of a safety factor for their particular tube.

For comparatively low-milliamperages, and longer exposure times, the heat from the focal spot of the tungsten button of the anode is transferred by conduction to and through the copper anode itself. The long time rating, therefore, depends upon the mass of the anode and the degree of conduction of heat from the tungsten button to the end of the anode stem assembly. This assembly usually terminates in some form of a radiating surface, which is either in contact with the oil, in case of oil immersed tubes, or terminates in a finned radiator for maximum dissipation of the heat in oil or air. The safe maximum temperature of this anode stem assembly must be definitely limited to a certain specified temperature in order to prevent damaging the seals between the anode stem and the glass envelope of the tube.

Tube overloads that are caused by a high or excessive milliamperage show up as damage to the focal spot area on the tungsten button. This is evidenced by a melting of the tungsten and may show up as a glazed focal spot area or an actual melting and bumpy condition of the focal spot surface. A high overload of the anode of the

tube may also cause the tungsten or focal spot surface to crack open. This may be just a straight crack or it may be multiple cracks, but it is a definite evidence that the tungsten proper has been overheated. Tungsten melts at approximately 3400° C. Copper melts at 1083° C. You will see, therefore, that there is a considerable difference between the two metals which definitely established the nature of the overload on a tube. The evidence can be very plainly diagnosed with a little consideration of these two different melting temperatures.

While a high-milliamperage overload usually melts the tungsten and does not affect the copper backing because it is not on long enough, and a low-milliamperage overload usually melts the copper but does not affect the tungsten, there are occasionally certain types of overload which do not show any melting of either the tungsten or the copper. In the modern oil immersed shockproof tube the cooling of the anode stem assembly or anode radiator is usually more efficient than the air cooled tubes. On a low-milliamperage overload, which is not quite enough overload to actually melt the copper, there may still be definite evidence of overload by the fact that the entire temperature of the head and the oil in the head exceeds definite safe limits. This may be evidenced by a bulging of the transparent plastic window or may be evidenced by breaking the warning signals or red buttons on the end of the shockproof oil immersed tubes. Whenever this is done, it is definite evidence that the tube has been overloaded on low-milliamperage for too long a time. We have had some tubes which have reached a high enough temperature in the tube head to actually melt the solder on the ends of the expansion bellows at the end of the tube. While these tubes usually fail, there have been instances when the actual tube insert is still operable even after all of this overload. This, however, is lucky. Fortunately, the tubes are conservatively rated, and they will withstand a certain amount of overloading without damage. However, never rely on the conservative rating of the tube. Operate them below the actual ratings wherever possible.

There is a very definite reason for the three rating charts. On single phase operation, full-wave rectification permits the highest tube rating.

The half-wave rectifiers (single or two valve units) have a somewhat reduced rating. The reason for this reduction is that milliamperage rating is based on the peak current, and the actual peak current on half-wave units is double the peak current on full-wave. The actual milliammeters, of course, only read the average current, and on half-wave you have every other impulse completely omitted from the tube current.

On self-rectified units, the rating of the tube is reduced considerably even from the half-wave (single-valve) rectifier. The reason for this is that the ratings of the full-wave and half-wave are based on heating the tungsten button during radiography to an incandescent temperature, not quite reaching the melting point. On self-rectified, however, the heating of the tungsten must be kept below the incandescent or red heat stage. The reason for this is that if the anode reaches a red heat, there will be electrons emitted from the anode during the inverse cycle of the voltage from the self-rectified high-tension transformer. If this occurs, the electrons will be carried across the gap between the anode and the cathode structure, and will bombard some part of the filament structure. This is known as back emission and results only from an overload of the anode. This causes a burning out of the filaments of the cathode structure, and very often causes melting of some part of the cathode focusing cup or cathode stem assembly. On self-rectified equipment such overloads are common and are the direct result of heating the tungsten button to an incandescent stage, which is beyond the published ratings for self-rectified operation. Quite often the ratings of half or full-wave rectification are accidentally used for these self-rectified tubes which always results in damage.

The preceding represents the common causes and effects of overloading the tubes. Excessive heating is the direct cause of all of it. So far, nothing has been mentioned about gassy tubes or about voltage strains of voltage overload. This is an entirely different subject.

The x-ray tube depends upon a state of high evacuation for its successful operation. Nevertheless, there is always a slight amount of gas present.

During the manufacturing process of the tubes, all of the metal parts used in the tube must be carefully evacuated by casting in a vacuum and by heating to a high temperature which nearly approaches the melting temperature under a high vacuum to exclude all gases which would normally be contained within the metals themselves. When tubes are allowed to stand without being used or operated over long periods of time (weeks or months) they usually accumulate a small amount of gas within the envelope of the tube. Therefore, it is recommended that new tubes when first put into operation be carefully seasoned to prevent the small amount of gas from destroying the tube. If they are seasoned properly, that is, operated at the 3 milliamperes at about 50 KVP for a period of time approaching its rated fluoroscopic exposure time, this small amount of accumulated gas will usually disappear, and the x-ray tube will function normally from that time on.

Gas in a tube is usually evidenced by milliammeter fluctuations. A very slight amount of gas in the tube will often cause voltage surges and yet may not be sufficient to indicate on the milliammeter as an actual current variation. Occasionally small clicking noises are heard inside of the tube housing. These may or may not be accompanied by a fluorescence or flashing of the tube. This small clicking noise usually indicates a gassy condition of the tube, providing it is not a loud click which may indicate a sparkover through the oil or some other sparkover or failure of insulation within the tube head. A slight click, however, usually indicates gas and the x-ray tubes are not to be operated in this condition.

If this tube is very gassy, flashes of green or blue light can be seen within the tube envelope if viewed through a piece of lead glass placed over the aperture with all other filters removed. Such flashes will also be indicated by rapid fluctuations of milliamperage as indicated on the milliammeter. If the filament of the tube remains comparatively constant, but considerably rapid milliamperage fluctuations are occurring, it is a fairly sure sign that the x-ray tube is gassy; and if this is true, it should be replaced at once. A gassy x-ray tube generates high-voltage surges which are considerably in excess of the normal voltage ratings of the installation, of the cables and equipment and may, therefore, cause damage. It may also cause puncture of the x-ray tube insert envelope, and may even shatter the entire insert. It is, therefore, better to remove the tube as soon as such rapid milliamperage fluctuations are observed to prevent further damage.

X-Ray tubes have a definite voltage rating, depending upon the type of tube and high-tension circuit used. If these voltages are exceeded, there is always danger of a puncture of the x-ray tube envelope. Over-voltage may also cause failure of insulation of other parts of the circuit, especially the high-tension shockproof cables.

Occasionally there may be a gradual fluctuation of milliamperage, as indicated by the milliammeter. This may or may not be traceable to fluctuations in the filament circuit. These may be caused by actual line voltage fluctuations and can be prevented by the installation of a stabilizer for maintaining constant voltage to the x-ray filament circuit, regardless of the change in the incoming line voltage. This is plainly evident by watching both the primary voltmeter or kilovolt-meter and

the filament meter at the same time. If during operation, both meters fluctuate, it is usually a sure indication that the filament variations are being caused by the line voltage fluctuations. In such cases a stabilizer is indicated.

Filament variations may also be occurring from loose connections in the filament circuit or from poor contacts between high-tension shockproof cables and terminal receptacles either in the high-tension transformer or in the x-ray tube proper. In this case the filament meter will fluctuate, and one may even notice the difference in temperature of the filament by observing its brightness with the exposure off while certain parts of the circuit such as the high-tension shockproof cables are moved to determine the point of loose contact.

Occasionally there are filament failures in the x-ray tube which are caused by an over-voltage being applied to the filament itself, even though there may be no exposure on the x-ray tube. Such over-voltages may occur from accidental grounding or from a temporary increase because the filament limiting resistors are not properly set and someone accidentally turns the filament control so that the filament is actually overloaded. Such overloads are evidenced by a large melted ball forming at the ends of the open circuited filament which may be readily observed with the eye. Sometimes, however, the filaments burn out from being left on at a normal temperature for long periods, such as leaving the filament on over a holiday or over a week-end. In such cases, the small ball on the ends of the burned out section of the filament is extremely small and very hard to see without a microscope. The evidence there, however, is that there is a discoloration of the entire cathode cup which is evidenced by an overheating of the adjoining surfaces of the anode focusing cup.

It is plainly seen, therefore, from a study of the above that tubes may always leave a telltale mark as to the cause of the failure or the cause of the overload of the tube. Careful study of each tube presents definite evidence of these various factors. The tubes are carefully tested during each process of manufacture. They are inspected many times and are sent out in excellent condition. There is no possibility of overloading of the focal spots in factory tests. Occasionally, however, during transportation there may be some possibility of an oil leak which might introduce air into the tube head. Therefore, it is recommended that all tubes be carefully inspected when they are first received without turning on the high-tension, and inspected for air bubbles, overloaded spots, or any other defects; and such should be reported immediately without turning on the high-tension current. Naturally, if a tube is operated with air in the tube head, you are effectually reducing the insulation between the x-ray tube and the grounded housing and failure from sparkover or from puncture of the tube is likely. A slightly gassy tube will not cause melting of the spot unless operated in this condition and the milliamperage has been allowed to fluctuate and to exceed the safe limits. Remember the difference in loading between self-rectified, half-wave, and full-wave operation. It is doubly dangerous to overload a self-rectified tube because of the danger of back emission.

The following outline of common tube difficulties may prove helpful.

1. Glazed Focal Spot.

   A. Results from overload.
      1. Use of wrong rating chart.
      2. Inadvertent application of power (to wrong spot in case of double-focus tube).
      3. Faulty control.
         a. Error in timing device.

b. Faulty milliampere meter.
c. Faulty, incorrect calibration.

B. Tubes with a glazed focal spot should be operated with lower load energies to insure a useful life.

2. Cracking or Splitting of Target.
   A. Frequently the result of high-milliamperage operation due to the rapid expansion of tungsten as a result of heat.
      1. Usually increases with tube life.
   B. In this condition, longer tube life can be obtained with lower load energies.
   C. If the crack extends through the tungsten to the copper backing (in stationary anode tubes) the tube should be considered useless.

3. Melting of Copper.
   A. Usually the result of excessive heating (overload).
   B. Melted copper usually increases the pressure due to gas liberation within the tube, thus impairing the stability of the tube's performance.
   C. If the copper is melted, and the tube is unsteady, it should be replaced.

4. Gassiness.
   A. Usually due to liberation of occluded gas by excessive heat localized at some part within the tube proper.
      1. Most common to x-ray tubes operated at relatively high-voltages.
      2. Not necessarily an indication of air within the tube envelope.
   B. Purple or Apple Green Fluorescence of the Glass Envelope.
      1. This is due to the impact of scattered electrons from the anode. This fluorescence is not significant.

5. Incandescent Spots on Target During Operation.
   A. Due to incomplete removal of foreign matter from the target during the manufacturing of the tube.
   B. This is not important since, with continued use, these spots will eventually disappear.

6. Tube Puncture.
   A. High-Tension Surges.
   B. Excessive metallic deposit on inner surface of tube envelopes.
   C. Non-Shockproof Tubes.
      1. Dusty Tube envelopes.
      2. Operating Tube in proximity of sharp points.

The only thing that remains is the application of these known facts, and to avoid complications before they start. How can this be done?

A. Take nothing for granted.
B. Check all conditions of operation.

Now to engage in a review in the form of a few questions and answers.

1. *Does a gassy tube always show visible manifestations of fluorescent flick through the bulb?*

Ans. No. While instability in an x-ray tube is usually accompanied by a positive ion discharge, the light from the filament may obscure the light produced by such discharge and so no flash is seen. As a rule, the

stability of operation (through meter reading) is a better guide in the determination of a gassy tube. The stability of operation can be judged provided other conditions in the generator circuit are under close control.

2. *When a "click, click" noise occurs inside a tube housing, what may that signify?*

Ans. The clicking which may occur inside a tube housing is usually a discharge from some point at high-voltage to ground through the oil. It may be due to sudden surges producing potentials high enough to overcome the dielectric strength of the oil, or it may be that the oil itself has become contaminated. This can happen if *air enters* the housing inadvertently.

3. *Assume a tube to be gassy, would that condition contribute solely to a melted focal spot, or melted copper surrounding the button?*

Ans. Damage to the anode, either to focal spot or the copper, cannot be attributed to a gassy condition in the tube. Such damage is the result of overload. If the tungsten is damaged the tube may be assumed to have been overloaded with a high energy exposure of short duration. If the copper is melted it is an indication that an exposure of long duration, possibly with low energy, where the heat production was greater than the heat dissipation.

4. *A tube being gassy, will that contribute to its puncturing in the glass envelope?*

Ans. A gassy tube is very likely to puncture in the glass envelope. The reason for this is the stability of operation depends upon accumulation of negative charge on the glass walls of the tube which must be of constant value. If ionization occurs in the tube due to a gassy condition, some of the negative charge is suddenly neutralized giving rise to high surges which may damage the tube envelope. A tube which has been punctured has usually been made gassy through abuse before the puncture occurs. What is that abuse? Overheating.

5. *What are the causes of filament failure although the filament current was normal, with respect to self-rectified units?*

Ans. The cause of filament failure cannot be definitely determined without close visual inspection after the cathode has been removed from the damaged tube. However, the most frequent cause is back emission. Such back emission results when the anode becomes a cathode and AC goes through, due to heating the focal spot sufficiently to emit electrons, thus bombarding the cathode.

6. *Have filaments been known to fail because of inherent weakness?*

Ans. Filament failures due to inherent fault in the filament wire in an x-ray tube are so rare that they are practically unheard of.

7. *Is it desirable to investigate all tubes before energy other than filament current is applied to ascertain the presence of air bubbles in tube housing and why?*

Ans. Yes, the presence of air bubbles either through air leak or improper filling or faulty pumping mechanism, etc., will or may cause trouble because these air bubbles may become located in a position where the insulation within the housing is endangered.

8. *With a filament lighted, although the cathode cable contact is poor, what manifestations take place?*

Ans. Fluctuation in the filament temperature may be observed, or if such fluctuation is not sufficient to be evident, fluctuation in the milliamperage incident to temperature fluctuation may be observed. Another check, remove the cathode cable and feel the contacts, if hot, this is an indication of a poor connection.

9. *How can one cure "corona" leak in cable terminals?*
Ans. If corona exists it is manifest by corrosion (due to ozone and nitrous oxide). This is undesirable. The best solution is to have no air present in which the ozone can originate. One solution is to occupy the air space with petroleum jelly, (Never use "K-Y" jelly.)

10. *Has focal spot damage other than overload ever been known?*
Ans. Yes, and if tubes are used at maximum ratings at high MA, say 100 or over, the focal spot temperature is high indeed. Under such conditions it cools very rapidly by radiation, so that the surface of the tungsten is caused to expand and contract per each alteration of supply voltage. This steps up fatigue effects in the tungsten, ultimately causing it to crack. In this way, the tube reaches the end of its normal life.

11. *In overloading an anode with excess heat, what evidence presents itself although the focal spot is undamaged?*
Ans. If excess energy is applied to a copper anode system the copper may actually be molten before the tungsten is above 3000 degrees centigrade. The melting point of the copper would be about one-third of that value. Another possible evidence of course, is that the tube may be made gassy by such a procedure resulting in a puncture.

To review and comply with the needed tests.

1. Check milliampere meters with another that is known to be accurate.
2. Check maximum operating voltage with sphere-gap either surging, direct or inverse.
3. Check timers at the load being used.
4. Check cathode contact.
5. View tube target before use and application of high-voltage.
6. Check contactors for smoothness and cleanliness.
7. Check ground connection.
8. Check for air bubbles in tube.
9. Check cleanliness of terminals.
10. Care in loading of the tube through calibration use, and observation of cooling time.

Tube Type__________ Serial No.__________
Generator Type __________ Make __________
Type of Circuit __________

User Name__________
Date__________
Serviceman __________

1. Replacement______New Installation__________
2. Condition on Unpacking __________
3. Filament Lighted only, condition of Anode__________
4. Inspection for Air Bubbles __________

5. Was MA Meter placed in High-Tension Circuit. ____________
6. Was Sphere-Gap in Circuit ____________
7. Was MA Meter reading steady at 5 MA 50 KVP Operation
8. At calibrated value of 80 KVP what readings were obtained with sphere gap on drawing spheres together.

		Sphere-Gap Readings	Surge Volts
______ MA	80 KVP	______	______
______ MA	80 KVP	______	______
______ MA	80 KVP	______	______

9. At the same settings not above - Surge KVP. That is sudden switch closure and gap crash-over.
10. How did HT MA Meter compare with control or other MA Meters
11. On Self-Rectified outfit give sphere-gap inverse readings versus radiographic KVP calibration.

		Inverse	
______ MA	80 KVP	______	KVP
______ MA	80 KVP	______	KVP
______ MA	80 KVP	______	KVP

12. On Self-Rectified or Single Valve Outfit, has contactor been provided with Surge Resistor ____________
13. On Mechanical Rectifier or Single Valve have High-Tension Resistors been installed or R. F. chokes ____________
14. If MAS Meter is included has it been checked ____________
15. Has Timer been checked at maximum load for error and how much ____________
16. On Rotating Anode Tube state Max. Filament Current
 ____________ Small ____________ Large
17. Have valves in generator been checked ____________
18. Have contactor points been cleaned. ____________

COOLING - There are two points to be considered in the heat dissipation of radiographic x-ray tubes. One with the capacity of the anode to store heat during a single exposure and to sustain a high-intensity load on a small focus area: the other with the capacity of the anode to dissipate heat from the tube and to withstand repeated exposures. The first principle has best been solved by the rotating anode tube which will be discussed in a later paragraph.

There are three methods of dissipating heat, or cooling x-ray tubes, namely, radiation, conduction and absorption.

In an "air-cooled" tube the target increases in temperature until its radiation balances the power input. All this energy is radiated through the glass wall and heats it. This is really the limiting factor for continuous operation and can be raised by directing an air blast against the bulb. Cooling by radiation is employed for air-insulated therapy tubes and for rotating anode tubes.

In the conventional stationary anode radiographic tube, a tungsten target is embedded in a copper anode, and the heat generated on the face of the anode is dissipated by conduction out through the copper stem of the tube, which generally has a radiator to increase the cooling efficiency.

Absorption is effected by pumping a cooling medium, such as oil or water, through a hollow anode stem. While the heat conductivity and heat capacity of water is about eight times that of oil, nevertheless, oil is generally used for modern tubes since it permits operation of grounded cooling systems and eliminates the electric hazard incident to leakage. This method of cooling is employed for therapy tubes.

CATHODE DESIGN - The function of the cathode is supplying electrons and confining them to a beam of the exact size and shape.

In modern x-ray tubes, the cathode consists of a tungsten filament mounted in a slot, or cup, which serves as a focusing device. The filament on being heated to incandescence by a current of a few amperes, emits electrons which serve to carry current through the tube. The electron emission increases very rapidly with increasing filament temperature.

The size, shape and distribution of the focal spot is governed by the shape of the filament and its position within the focusing device, the position of the focusing device in the bulb and the distance between the cathode and anode.

THE VACUUM - The gas pressure in a hot cathode tube must be below the point of cumulative ionization so that the emission may be controlled by the temperature of the cathode. Cumulative ionization is ionization which, starting with a few ionized atoms, spontaneously causes ionization of a great number which cannot be controlled. The principle demand is that there shall be so few air molecules that most of the electrons go from cathode to anode without colliding with one and causing ionization by collision. If the vacuum is not high enough the tube may operate, although fluoroscence and gas discharges are likely to occur. With large amounts of gas the vacuum will break down and the tube will be filled with a glow. Tubes have a tendency to gas at high-voltages for the excessive heating may release some gas.

THE ROTATING ANODE TUBE - The rotating anode tube permits increased radiographic detail without sacrifice in speed. Fundamentally, it involves rotation of a small focal spot with respect to the anode (and, therefore, distribution of the energy over a large area of the anode) without motion of the focal spot as far as the part to be radiographed and film are concerned.

As stated previously, it is the function of the anode to absorb and dissipate heat, and the rate of dissipation determines the capacity of the tube. The anode of the rotating anode tube is made to rotate at high speed (above 3000 RPM) and the focal spot area is thus continuously replaced by cool metal, permitting it to sustain a high-intensity load, approximately ten times higher than that of a stationary anode tube.

SECTION XXI

VALVE TUBES

VALVE TUBES - These are employed to rectify the high voltage supply. They permit the flow of current in only one direction and block the flow in the opposite direction. Valve tubes are similar to x-ray tubes in that they have two elements: one, the filament; the other, the anode. Valve tubes rectify an alternating current. It is easier for the current to flow from the electron emitting filament to the anode than in the opposite direction, as there are carriers for the current in the former direction, but not in the latter.

The valve tube would give off x-rays if there was a potential difference across the elements to accelerate the electrons toward the anode, but the filament is raised to such a high temperature (over 100 watts) that sufficient electrons are emitted to carry the current without offering resistance to the flow. As there can be no potential difference, if there is no resistance, the resistance of the valve tube in the cathode-to-anode direction is little more than that of a metallic conductor. The lack of carriers in the inverse direction produces a very high resistance in that direction and because of the lack of electrons from the anode, the valve will produce no x-rays.

Theoretically no x-rays are produced by valve tubes; however, in a practical sense, certain valves may give off x-rays during the inverse half of the cycle. These come from the cathode (while it is positive) and may amount to as much as would come from an x-ray tube operating at the same voltage at 15 microamperes.

VALVE CATHODE SOCKETS - To maintain the maximum safety factor against flash over on the compact style of a valve, the manufacturer sometimes uses a bakelite end cap rather than one of the metal style. It is, however, more difficult to affix the Edison screw base to these bakelite caps and if undue force is applied in screwing the valve into the socket, it is possible to shear the solder joint, between the cap and the metal insert in the bakelite cap.

Therefore, caution must be exercised when placing a valve into the transformer. Do not try to force it in too tightly; however, good contact must exist. Gentle turning of the valve is required until one feels the screw cap taking seat. Judge the pressure and tighten through your fingers. If the valve is forced in and the Edison base breaks off, a serious service problem results.

In the event the valve tube has a metal base clamped into place, be sure the clamp is securely fastened but not to the extent it will strain the glass seal.

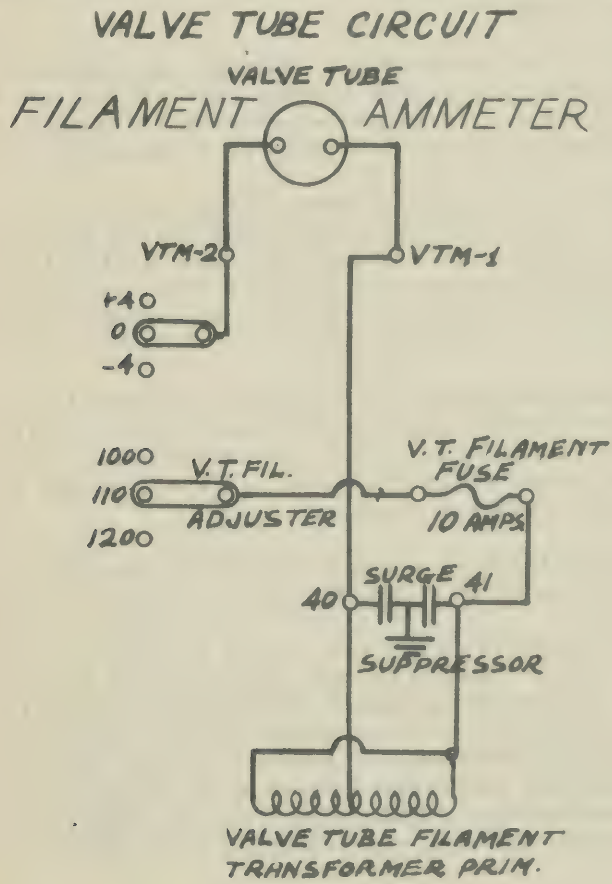
VALVE OPERATION - The proper functioning of a valve tube is of great importance from two viewpoints, the life of the valve tube and the high tension voltage delivered to the x-ray tube. The operating values of the valve tube filament suggested by the manufacturer should always be complied with. The voltage values stated in the various instructions represent the maximum voltage when the valve filament is lighted. The valves are generally connected in series in the high tension circuit, between the secondaries of the high tension transformer and the x-ray tube. When they are in series, the resistance of each valve tube affects the other.

Neglecting the resistance of the x-ray tube, then the voltage the x-ray tube has impressed upon it becomes a function of the voltage loss or drop across the valve tube. The greater the voltage drop in the valve tube, the less voltage the x-ray tube receives. The drop in voltage across the valve is a function of the filament heat. The resistance of conducting wires to the filament and cathode socket contact, therefore, must be kept at a minimum. If resistance is added, for example, during measurement of the valve tube voltage, there will be errors in-

troduced and when the valve is again put into use (without this added resistance) it will be burning at a higher than normal temperature.

Another consideration is line drop under x-ray load. Assume a valve has been checked at no load, and line supply is inadequate, then under load the valve voltage may drop below its required amount. In many instances, a valve tube booster system will compensate for this loss under heavy load as well as to increase the valve emission for the instantaneous requirement, but there are conditions of operation when no compensation takes place. Under such conditions, there is no alternative except to set the valve voltage up sufficiently high, so that on load it will drop to the normal amount. The essential equipment to check the valve tubes is as follows:

An accurate AC voltmeter that has a voltage range of not less than 0 to 15 nor more than 0 to 30 volts. Accuracy is most important. If a higher scale instrument is used, the reading error is too great.



A low resistance means to permit the valve to be connected when removed from its socket and out of the tank and provide means for connecting the voltmeter. Should a temporary means be made, such as a connecting plug to fit into the valve socket and wires attached to bring out the voltage for the valve, then these wires should be, at least, No. 10 stranded. In other words, the loss over this extension should be as low as possible. The best suggestion is a "Current tap, porcelain Hubbell #6298".

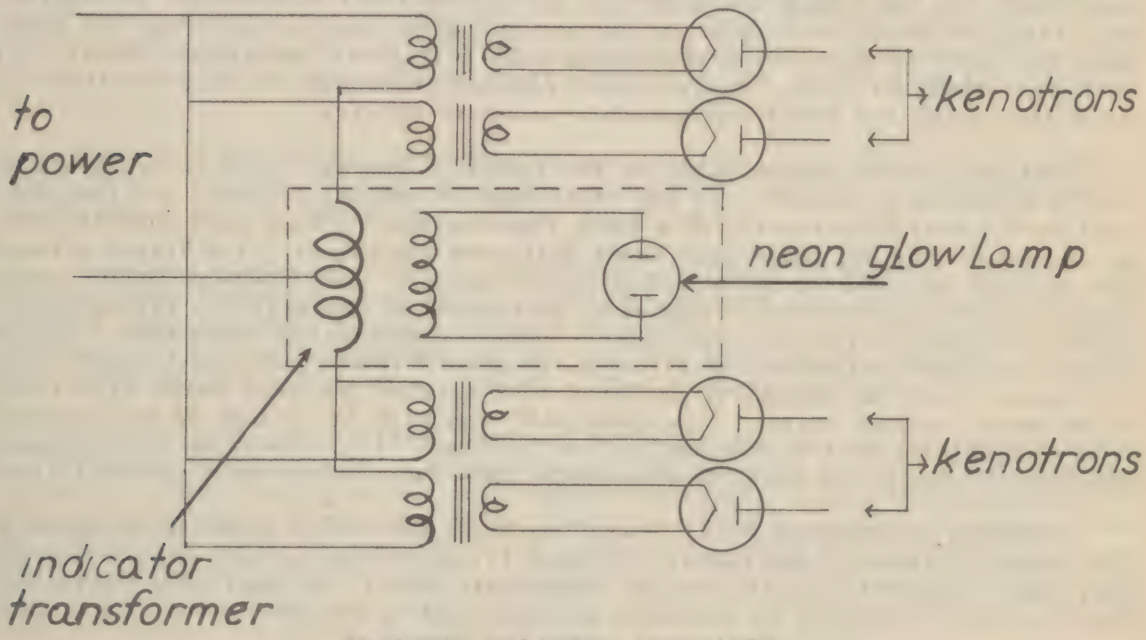
In the apparatus employing valves connected in parallel, the valves are all set separately. If the valve is held in place by a clamp, it may be possible to obtain voltmeter readings directly from the valve filament leads. The high tension voltage must not be turned on while making valve tube voltage adjustments.

It is to be noted that in some controls there is an amperemeter mounted in the primary circuit of the valve filament transformers. This is for the purpose of gauging the adjustment of the voltage supply to the primaries and may be used as a guide to valve heat performance. An illustration of this circuit is shown in the diagram above as used with the Picker 200 series. General Electric refer to their high voltage rectifier tubes as Kenotrons. The adjustments of the filaments of these tubes are indicated by the Kenotron Filament Indicator.

The Kenotron Filament Indicator is a pilot light which glows only when one or more of the Kenotron filaments is opened. Some apparently have gained the erroneous impression that the Kenotron filament indicator should glow to indicate that all filaments are burning rather than the converse.

Refer to the schematic diagram hereafter and note that one of the leads to the valve tube filament transformer is connected to the center of the primary winding of the valve tube indicator transformer. The two ends of the winding each supply two valve tubes. Normally, the current flowing in the two halves of the primary winding are equal and opposite. Hence no voltage is induced in the secondary winding and therefore the Kenotron indicator does not light up.

Should any of the valve tube filaments open up, the flow of current in the two halves of the primary winding will be unequal and a voltage will be induced in the secondary winding which will cause the Kenotron indicator to light.



KENOTRON FILAMENT INDICATOR

Thus, when an x-ray unit of this type is operating satisfactorily and all four valve tube filaments are lighted, the Kenotron filament indicator remains dark. A momentary glow appearing at the time of closing the line switch is normal and does not indicate a faulty condition. However, should the Kenotron filament indicator stay lighted, it is indicative of an "open" somewhere in the filament circuit, most probably a burned-out valve tube filament; however, it may also indicate bad contact in the cathode connection or fault elsewhere in the valve tube filament circuit.

VALVE TUBES FOR X-RAY GENERATORS

MACHLETT-GENERAL - Machlett Valve Tubes are high-voltage half-wave rectifier tubes of the two-electrode hot-cathode type, designed especially for use in X-Ray apparatus. Certain factors must be considered in connection with the design of circuits for their use and their proper adjustment upon installation. These factors are discussed in detail in the following paragraphs.

INVERSE VOLTAGE RATING - For satisfactory service, it is important that THE CIRCUIT IN WHICH ANY VALVE IS USED DOES NOT SUBJECT IT TO INVERSE VOLTAGES which exceed the maximum VOLTAGE RATING OF THE VALVE. Both external and internal design of the valve are partly governed by the inverse voltage at which it is intended to operate, so that if it is operated at higher voltages, instability, flashover, or puncture may result. Valves designed for oil-immersed operation cannot be used in air satisfactorily except at voltages sufficiently reduced to avoid flashover.

Valve Tubes are aged and tested at voltages sufficiently above their ratings to insure absolutely stable operation at rated voltage. The peak kilovoltage rating of each type is given in the Table of Ratings on Page 7 of this section.

LOAD CURRENT RATING - It is also of prime importance that the load current to be delivered does not exceed the valve ratings. Valves are rated on a current basis both for continuous operation and for intermittent operation. The continuous rating is based on a value of load current which does not overheat the anode when the valve is operated continuously with a filament temperature consistent with long filament life. Intermittent ratings are based on load durations in accordance with the usual radiographic exposure values.

The load rating values given in the Tables of Ratings, Page 7, are based on use in a full-wave circuit. If any other type of circuit is used, the load current rating must be corrected to a value representing the same *peak* current value as represented by the rated load under full-wave conditions. The listed ratings are *average* values as read by a D.C. milliammeter. For example, in half-wave circuits, the load current values must be reduced to one-half the rating values given. In other circuits, particularly those incorporating condensers, such as Villard and constant potential circuits, no such definite rule can be given, and the circuit must be carefully analyzed to determine the peak value of current to be passed by each valve. This value will vary with the values of various circuit constants as well as the average load current. If in doubt as to the proper adjustment, consult the Machlett engineering department before making installation.

FILAMENT ADJUSTMENTS - It is very important that valve tubes be operated at the proper filament temperature. Higher filament temperature than necessary shortens filament life, while too low temperature results in insufficient emission, which causes the anode to overheat and may lead to destruction of the valve.

The filament temperature can be controlled most accurately by adjusting the filament supply circuit for a definite voltage at the filament terminals with the valve in the circuit. A reasonably high-resistance voltmeter should be used for this measurement. Each valve is marked with data enabling the setting to be made to a definite filament current value, rather than voltage, by means of an ammeter, but as the filament characteristics change with use, all subsequent settings must be made by voltage. Constant voltage must be maintained for the life of the valve, for a given value of load.

For each type of valve, the proper filament voltage depends upon the load current to be supplied by the valve. The Table of Ratings indicates the valve for loads equal to the continuous rating or less. For loads higher than the continuous rating, the charts on Page 6 indicate the exact setting for any given load.

As the filament voltage is increased beyond the value corresponding to the continuous rating the normal life expectancy of the filament rapidly becomes less and less, so that it is important to conserve the life as much as possible by

turning on the filaments only just before an exposure is to be made and turning them off immediately afterward. When the load current exceeds the value indicated in the Table of Ratings "without automatic pre-heat", it is recommended that an automatic device be employed to raise the voltage to the required value an instant before the exposure and lower it to a stand-by value at the end of the exposure. The use of this "automatic pre-heating" is not essential to proper operation, but experience has indicated that the difficulty in insuring that the valves will be turned on only the necessary minimum length of time when depending on manual control makes it highly advisable to provide such an automatic device. The stand-by voltage should preferably be the value corresponding to the continuous rating, and in no case should exceed the voltage corresponding to the rated load "without automatic pre-heat".

The importance of these adjustments will be appreciated when it is realized that the average life expectancy of the filament at the setting corresponding to the "continuous" rating is approximately three times as great as at the setting corresponding to the "without automatic pre-heat" rating, and approximately eight times as great as at the setting corresponding to the "with automatic pre-heat" rating.

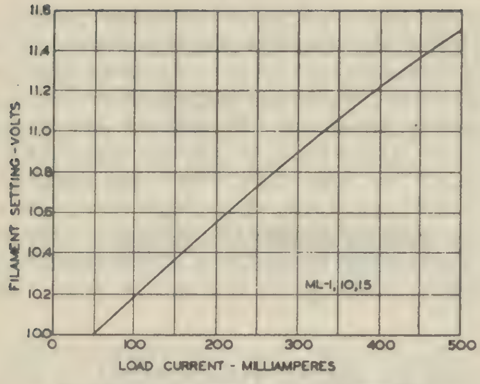
TESTING AND EXAMINATION - Each Valve Tube receives a careful test immediately before shipment. Immediately upon receipt it should be examined and tested to determine that no damage has occurred in shipment.

The valve should be tested in the type of equipment in which it is to be used at the highest voltage at which it is to be operated (but not in excess of its maximum inverse voltage rating), and with filament voltage set at the proper value. If there is no glow or sparking in the tube and the apparatus operates smoothly and normally, the valve may be assumed to be in good condition.

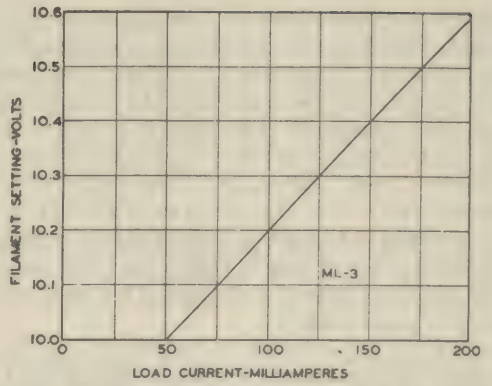
INSTALLATION - At the time of final installation, the highest load current at which the apparatus is to be used should be definitely ascertained, and the proper corresponding filament circuit adjustment carefully made in accordance with the instructions outlined above. The stability of the supply line voltage should be checked, to avoid the possibility of fluctuations which may reduce the filament voltage below the required value. *Voltage drop in the line when the load is applied should be taken into consideration, so that the correct filament voltage will be maintained during the load period.*

If the valves are one of the types intended for operation under oil, the container in which they are to be installed should be filled to the proper level with a good grade of insulating oil, free from dirt, moisture, or other impurities.

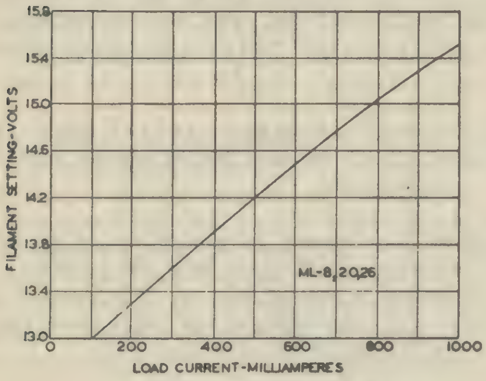
Adequate clearance must be maintained around the valves to avoid the possibility of sparkover to surrounding objects. Machlett valves may be mounted in any position with reference to the vertical.



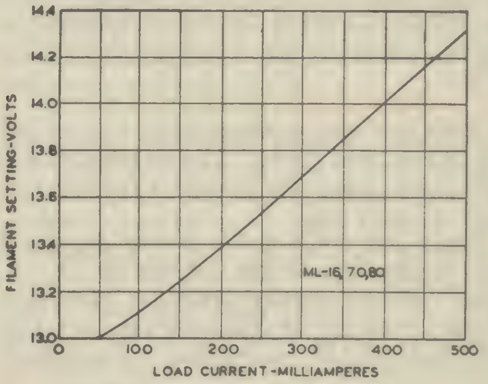
FILAMENT ADJUSTMENT CHART FOR TYPES ML-1, ML-10, ML-10B, ML-15, ML-15B



FILAMENT ADJUSTMENT CHART FOR TYPE ML-3

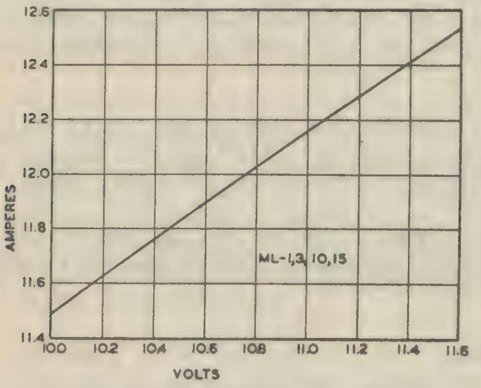


FILAMENT ADJUSTMENT CHART FOR TYPES ML-8, ML-20, ML-20B, ML-26

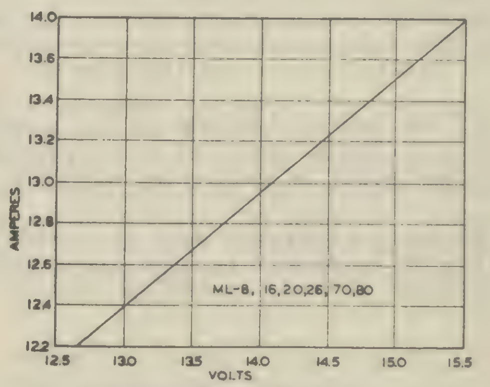


FILAMENT ADJUSTMENT CHART FOR TYPES ML-16, ML-70, ML-80

Adjust filament voltage for maximum required load as indicated by above charts. Load current values given in charts are based on full-wave circuit. For other types of circuits, determine the *peak* value of current to be passed by the valve, and adjust the filament voltage to the value corresponding to a full-wave load having an equal *peak* value.

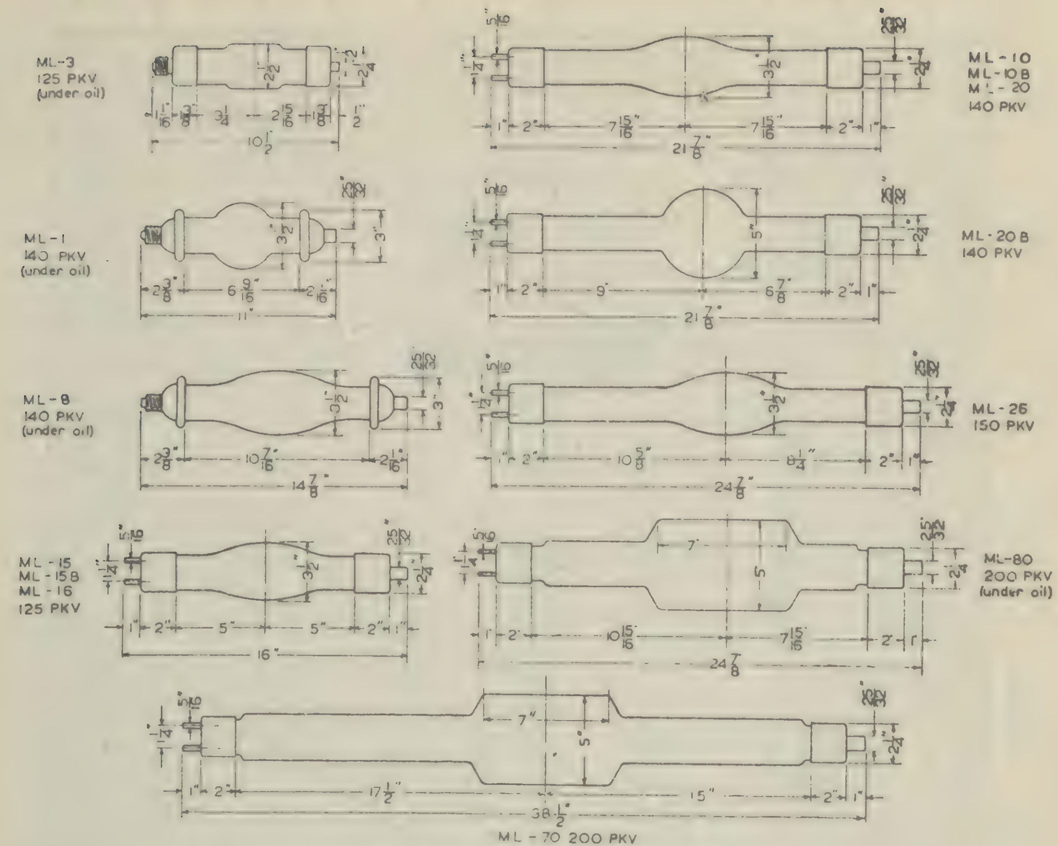


APPROXIMATE FILAMENT CHARACTERISTICS— TYPES ML-1, ML-3, ML-10, ML-10B, ML-15, ML-15B



APPROXIMATE FILAMENT CHARACTERISTICS— TYPES ML-8, ML-16, ML-20, ML-20B, ML-26, ML-70, ML-80

The above filament volt-ampere characteristics are approximate, being subject to small variations from tube to tube. Each valve is marked with the volt and ampere values for one or more points on the exact characteristic for the individual tube. By making the indicated correction in the above characteristics and referring to the proper filament Adjustment Chart above, the proper filament *current* setting for any value of load can be determined, so that the setting can be made with an ammeter. This applies only when the valve is new. All subsequent settings must be made by voltage.



Dimensional Data—Machlett Valve Tubes

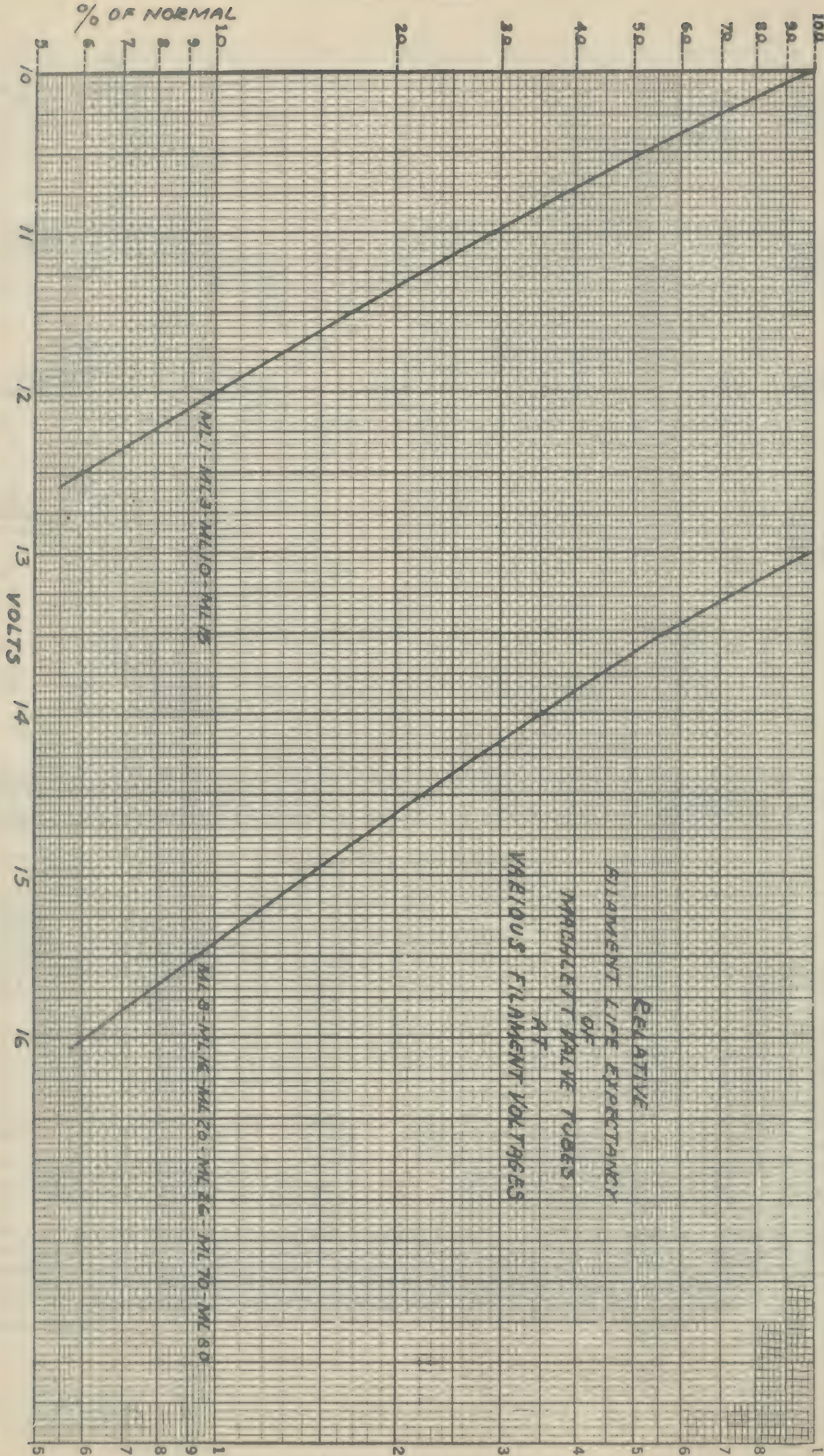
Notes: Types ML-10, ML-10B, ML-15, ML-15B, and ML-16 may be furnished with Edison screw base instead of prong base as shown above, if so specified when ordering. Types ML-1, ML-3, and ML-8 may be furnished with prong base instead of Edison screw base, if so specified when ordering.

Type ML-10B, ML-15B, and ML-20B are made of opaque black glass, being intended for use where the light from the filaments would otherwise be objectionable.

TABLE OF RATINGS

Cat. No.	Type	Maximum Inverse PKV**	For Use In	LOAD RATINGS—MA*			Filament Voltage—Continuous Operation
				Continuous	Intermittent Without Automatic Pre-Heat	Intermittent With Automatic Pre-Heat	
V-11	ML-3	125	Oil	50	200	——	10 Volts
V-12	ML-1	140	"	50	300	500	10 "
V-23	ML-8	140	"	100	500	1000	13 "
V-29	ML-80	200	"	50	500	——	13 "
V-24	ML-15	125	Air	50	300	500	10 "
V-26	ML-15B	125	"	50	300	500	10 "
V-30	ML-16	125	"	50	500	——	13 "
V-17	ML-10	140	"	50	300	500	10 "
V-18	ML-10B	140	"	50	300	500	10 "
V-25	ML-20	140	"	100	500	1000	13 "
V-27	ML-20B	140	"	100	500	1000	13 "
V-20	ML-26	150	"	100	500	1000	13 "
V-28	ML-70	200	"	50	500	——	13 "

*MA Ratings are based on use in full-wave circuits.
**At load values in excess of the continuous rating, inverse should be limited to usual radiographic voltages; i.e., not exceeding 125 PKV.


% OF NORMAL
VOLTS
RELATIVE
FILAMENT LIFE EXPECTANCY
OF
MACHLETT VALVE TUBES
AT
VARIOUS FILAMENT VOLTAGES

SECTION XXII

TIMERS

A timer is a mechanical device for controlling the flow of the current for different periods of time. An accurate timer is essential for uniformly good radiographic work. A good timer must be accurate in its range of exposure time.

There are three types of x-ray exposure timers in general use.

THE HAND TIMER - This is essentially a device that operates with a clock mechanism. The range of these timers is usually from 1/4 to 20 seconds. These timers are not accurate at the shorter exposure times (1/4 second or less). However, they are only used on low capacity equipment where small errors in timing are not critical.

THE SYNCHRONOUS MOTOR DRIVEN TIMER - This is actuated by an electric synchronous clock mechanism. These timers have a time range of from 1/20 of a second to approximately 25 seconds. These timers, when properly adjusted, are considered to be consistent enough for practically all times of exposure where the current does not exceed 200 M.A.

The primary x-ray circuit carries a relatively high current during the exposure, for example a self rectified unit operating at 90 KVP - 70 MA may draw as high as 70 amperes; therefore, a special type of heavy duty contacts is required. It would be rather difficult to build these contacts into the timing mechanism. Therefore, a complete timer consists of two parts, the timing mechanism and a contactor, the coil of which is energized by an auxiliary supply controlled by the timing mechanism for the proper interval.

AN IMPULSE TIMER - There are many variations and they are used for exposures above 200 M.A. and exceedingly rapid exposures 1/60th to 1/5th second. The impulse timers are designed to operate (make and break) at zero potential.

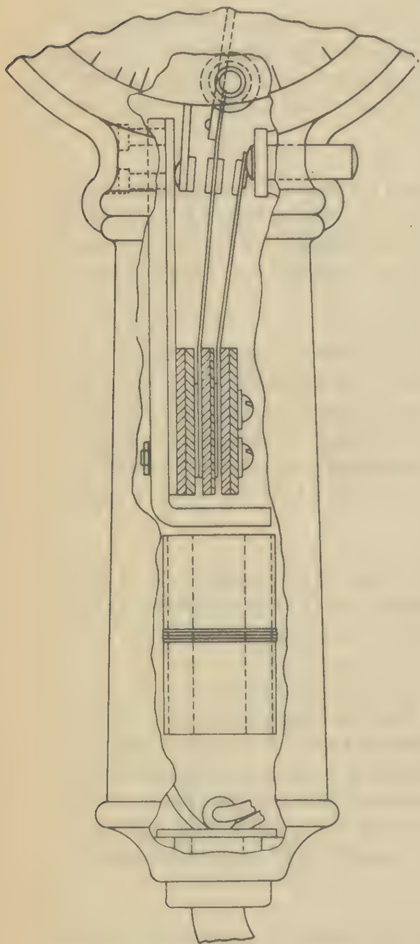
HAND TIMERS-CIRCUITS AND RATINGS - In the following diagrams, the "A" circuit is used whenever the timer contacts directly control the primary circuit. Note, that upon pressing the push button the circuit is first momentarily closed through the auxiliary resistance. This prevents full voltage being instantaneously impressed on the transformer and materially reduces any tendency toward surging. The "B" circuit is used when a magnetic contactor is interposed to close the primary circuit. In this case the auxiliary resistance, if used, would be incorporated in the magnetic contactor.

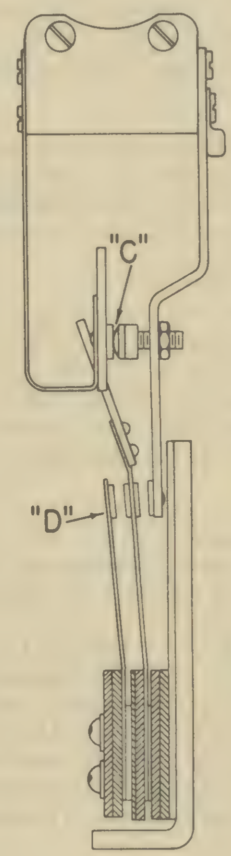
The hand timer is designed to handle the primary load normally required by an x-ray machine delivering a tube current of 10 M.A., 100 KVP, or equivalent. With units of greater capacity a contactor is interposed in the primary circuit and the timer used as a control only.

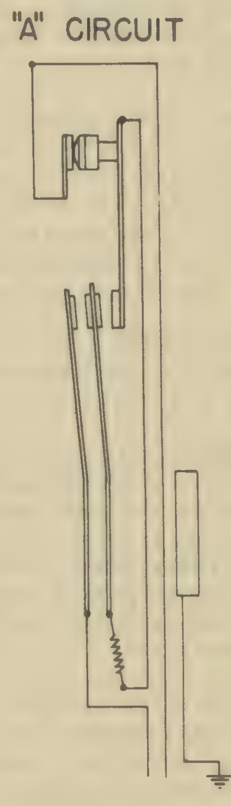
OPERATION - (G.E. New Style) To set the timer, turn the knob until the pointer indicates the desired time value. If the pointer should be turned past the desired time valve DO NOT TURN BACKWARDS, but rather PRESS THE RESET BUTTON. Where the correction is small the recommended procedure is to TAP the reset button gently.

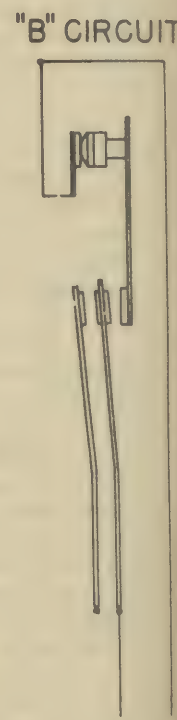
Settings for fractional second exposures should always be made with reference to the position of the indicator on the dial, never by the click method. The click method is not satisfactory. The use of hand timers for exposures less than 1/4 second is not recommended, as no timer of this type can be expected to provide the precision generally required for such exposures.

To make the exposure, press the push button quickly and firmly ALL THE WAY IN. This is important. Failure to press the button all the way in, or to press it in too slowly, probably accounts for most of the contact difficulty and resistance unit failure experienced.









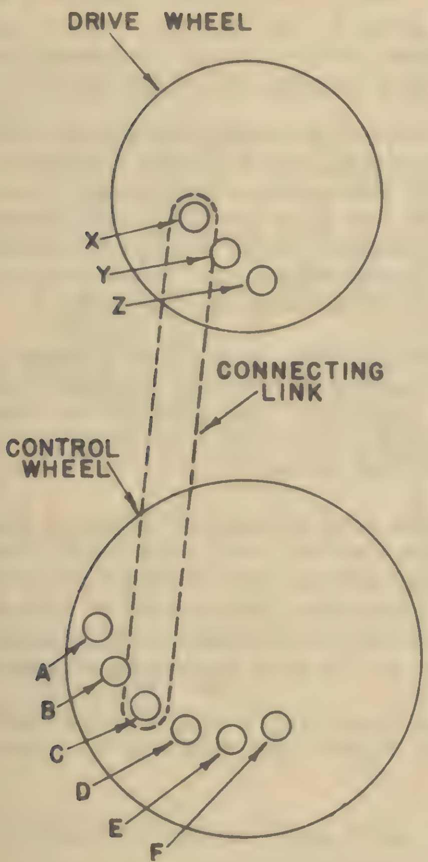
ACCURACY - The use of the word ACCURACY in describing any timing device should always be qualified. The dictionary definition of "accurate" is "exact, precise, free from error". The only literally accurate timer is the impulse timer, yet other timers, even though not literally accurate over the entire range, may have an allowable error so small as to be unobservable in the final result. In this instance it is proper to say the timer is accurate if it is understood that it is with respect to the end result.

Bear in mind, however, that the relative error is greater at short time settings than at long time settings, and also that a given error may not be objectionable on one film in the case of a long exposure and not acceptable in the case of another of short exposure.

SERVICE - (G.E. New Style) To correct timing, first remove the three screws in the back and expose the mechanism. Time control is obtained by varying the combination of holes in the driver and oscillator to which the connecting link is screwed until a combination giving the right time is found. The first timers manufactured provided two screw holes in the driver, and three in the oscillator. Present timers have three screw holes in the driver, and six in the oscillator. The principle of adjustment, however, is the same.

The following chart shows the order in which various combinations affect timing. The letters and figures designating screw holes do not appear on the timer. Having determined the combination being used and knowing whether the timer is fast or slow it is a simple matter to select a new combination in the direction indicated by the chart.

The chart is arbitrary only. Occasionally two combinations giving nearly the same time value, or even in reverse order from that given, will be found. This is normal. It is only necessary to find a combination which gives the desired time value.



FAST

X - A
Y - A
Z - A
X - B
Y - B
Z - B
X - C
Y - C
Z - C
X - D
Y - D
Z - D
X - E
Y - E
Z - E
X - F
Y - F
Z - F

TIME

SLOW

TIMING CHART

Drive Wheels with 3 Holes--Consider these holes as X, Y, Z.

Control Wheels with 6 Holes--Consider these holes as A, B, C, D, E & F.

Use care when working as the parts are small and easily lost. Should the washer be omitted, inconsistency in timing may result.

Be sure the washer is concentric to the screw and not caught under the shoulder. Tighten the screw firmly so that it does not come loose after you have finished the job.

The circuit opening contact should be adjusted with sufficient pressure to maintain positive contact. To check, place a piece of paper between the contacts and withdraw. Noticeable resistance to withdrawal should be felt. To readjust, bend the spring slightly.

The circuit closing contacts should seldom require attention. In the open position a space of 3/64 inches should exist between contacts.

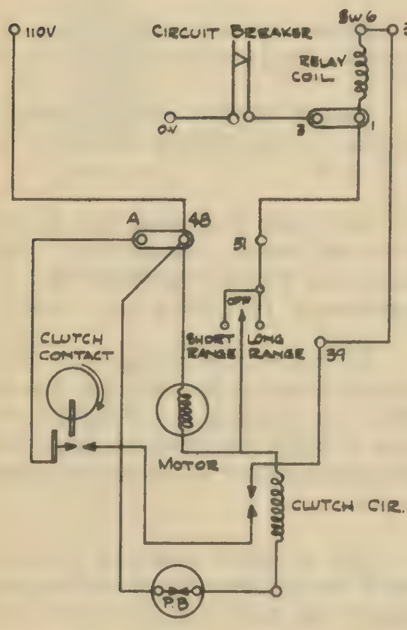
Any of the contacts may be polished by drawing very fine (#000 or finer) sandpaper between

them. Be sure all traces of sand are removed after this sanding. Drawing a strip of clean paper through the contact effectively removes the sand.

SYNCHRONOUS INTERMEDIATE TIMER - (Picker) The intermediate timer is operated by a small synchronous motor which runs a set of idler timing gears, one set of gears for the short time range, the other set for the long time range. Either set of gears is mechanically engaged by means of the combination range selector and on-off switch.

The time is set by the selector switch on the front panel of the timer which controls the position of the contact opening member. A cork-lined clutch, controlled by a relay, is mounted on the same shaft with the idler gear and contact opening member. The clutch relay when energized mechanically presses the clutch, thereby engaging the moving gear to revolve the contact opening member. When the member has revolved to its lowest position it opens the normally closed timer contacts which terminates the exposure.

INTERMEDIATE TIMER CIRCUIT



The timer electrical circuit consists of three parts as shown in the diagram: the motor circuit; the clutch relay circuit; the supply to the contactor coil through the timer contacts.

The motor circuit is indicated by the circled lines. The supply for the motor is obtained from the 110 volt line connected to terminals 51 and 48. In most controls this supply is taken from the control board auto-transformer. The motor is energized by the series on-off switch which also selects the time range.

When the push button is pressed voltage is supplied from terminal 48 through the push button and clutch relay coil to terminal 51, thus operating the clutch relay and performing the operation described above.

The contactor coil circuit is supplied from terminal 51, through the coil, the main timer contacts, and the contacts of the clutch relay to terminal 48. Therefore the contactor will be energized to close the primary circuit to the high tension transformer until the timer contacts are opened by the contact opening member or the push button is released

SERVICE-G.E. SYNCHRONOUS TIMER - Clean index plate teeth and place a small amount of Door-Ease Grease on toothed index plate teeth, and vaseline on motor-driven gear.

Clean out any dirt in motor-driven gears and use a small amount of vaseline.

Oil Motor bearings with a good grade of light motor oil.

Check pilot light socket for proper contact and tighten light.

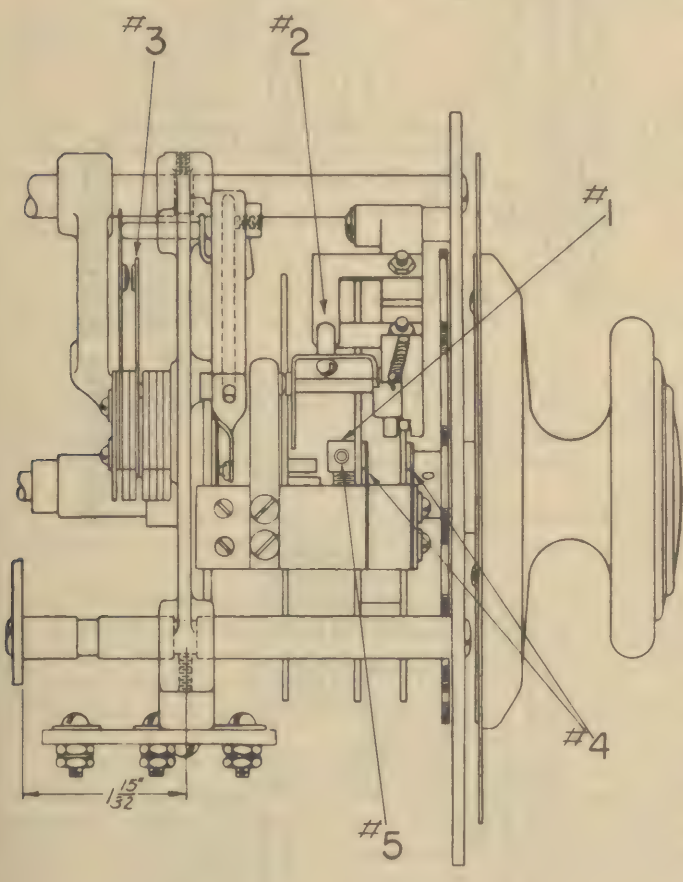
Inspect make and break contacts. Clean with crocus cloth if necessary.

Set time on 19-3/4 seconds and make an exposure to see that the recoil of timing disk does not alter the timing setting. If this changes, increase spring tension on the dog of the index plate.

Remove contactor housing. Repair and tighten any faulty electrical connections. Inspect and clean contactor contacts. Replace housing.

Inspect connections and contact of push button. Clean and repair if necessary. Timer should now be checked for proper timing, using spinning top method.

ADJUSTING TIMER - Referring to the illustration of the timer, the make contacts (#1) and break contacts (#2) should be checked to see that contacts are aligned properly and are parallel.



Clean *make* and *break* contacts with crocus cloth. The approximate spacing for make contacts is .018" and for the break contacts .014".

Clean clutch face plate surface and the friction pads with carbon tetrachloride.

Clean surface of plate contact disk with carbon tetrachloride, being sure that the tension on the sliding disk is sufficient to make proper contact.

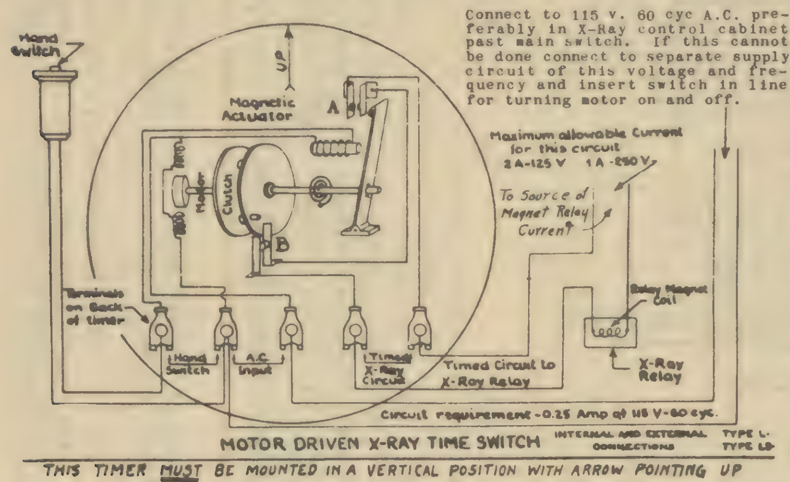
Adjustment of the make contact can be made by loosening the set screw and turning the make contact screw. The adjustment of the break contact can be made by bending the contact fingers.

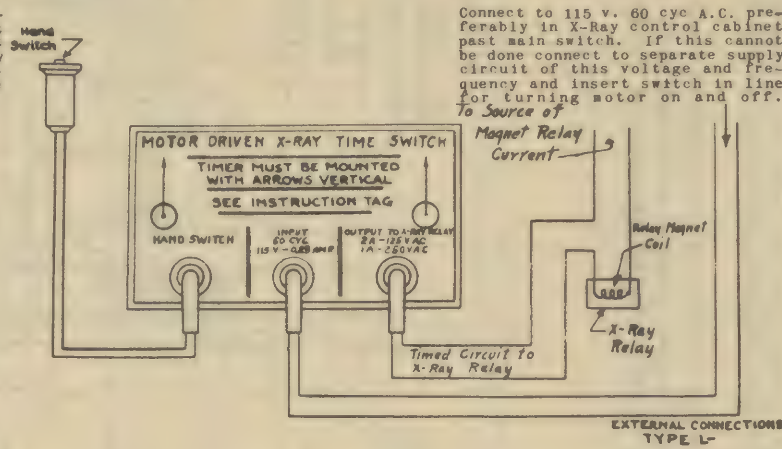
If the coarse adjustment of the time is necessary, set dial on the shortest time and loosen the set screw which is located in the square bakelite mounted between the two metal disks. Move the disk slightly clockwise when facing the front of timer for a shorter time, and counterclockwise for a longer time, being sure the dial does not move from its original position.

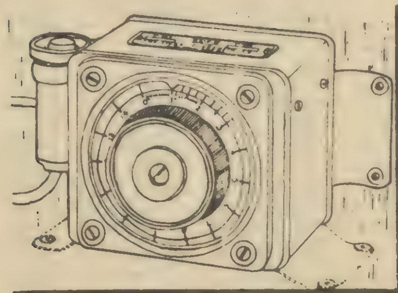
For finer adjustment, loosen the set screw and turn contact screw a few degrees for each adjustment until proper time is obtained. Clockwise decreases the time and counterclockwise increases the time.

Check to see that, upon completion of an exposure, the interlocking contacts are open before the break contact opens. This can be checked by operating the timer disk and solenoid manually. See that when the interlocking contacts close they have a positive wiping action.

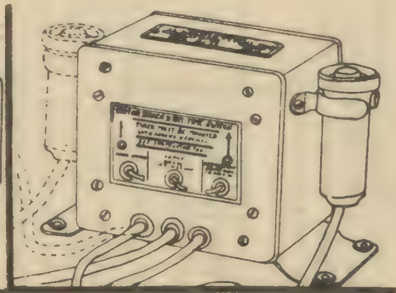
METHOD OF MOUNTING







Bracket can be applied to back of Timer for wall mounting. (Dotted lines indicate foot bracket in position for shelf mounting.)



REAR VIEW OF TIMER
Dotted lines indicate position of Push Button Control when mounted (optionally) on other side of Timer.

Set timer on 19-3/4 seconds and make an exposure to see that the recoil of timing disk does not alter the time setting. If it does change, increase spring tension on the dog of the index teeth.

LIEBEL-FLARSHEIM SYNCHRONOUS TIMER - Sketches show diagrammatically the internal and external connections and the method of mounting the Liebel-Flarsheim Synchronous Timer.

ADJUSTMENT - This timer was checked, tested, and accurately set to give exactly the exposures indicated on the dial. However, on any given installation, the magnetic switch may have characteristics which cause it to have greater "lag" when it makes, than when it breaks, or vice versa, and adjustment to offset this lag may be desirable.

To take care of the above, the timer is provided with a "Zero Adjuster".

WARNING - Before attempting to change this "Zero Adjuster" make absolutely certain that the timer is correctly installed and that the trouble is not to be found elsewhere. It is safe to assume that the timer functions satisfactorily and accurately and no adjustment should be attempted unless the x-ray exposure time has been checked by proper means (such as a spinning top) and you are absolutely certain that adjustment of the timer is needed to offset conditions in the magnetic relay switch.

TO MAKE ADJUSTMENT - The "Zero Adjuster" is within a hole in the timer dial underneath the setting knob, but it can be reached *only* when the dial is set on the 1/10 second calibration.

To expose the "Zero Adjuster" screw, first place dial on the 1/10 second setting. Then remove screw from center, lift off knob and in the dial you will find a hole marked "Adjusting Screw". As above mentioned, this hole will uncover the adjusting screw only when the dial is turned to the 1/10 second setting (this position can be reached by turning the dial as far as it will go (but do not force) in a clockwise direction.)

As marked on the dial, turning the screw clockwise decreases the exposure time, counterclockwise increases it.

Within a one-turn range either way, this Zero Adjustment screw may be moved to increase or decrease the exposure time to properly compensate for the characteristics of the magnetic switch. Fractional turn adjustments should be made and then the actual x-ray exposure time re-checked.

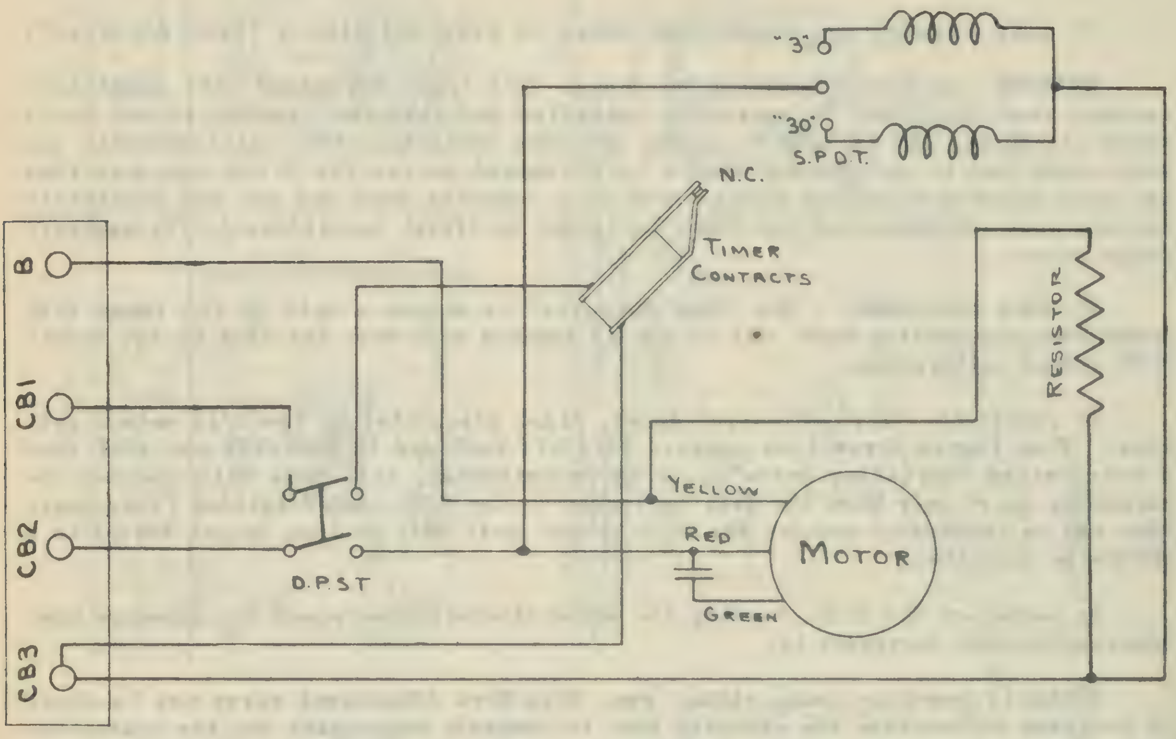
NOTE - Do not under any circumstance turn the screw more than one turn to the right or left from its original position.

WESTINGHOUSE SYNCHRONOUS TIMERS - The Westinghouse Timing device is operated by a synchronous motor that runs with a constant speed of 1800 r.p.m. The timer employs four terminals. These terminals are B, CB-1, CB-2, and CB-3. A hook-up of this timer is B and CB-2; 110 volts inlet. B and CB-3 is a push button connection, and CB-1 and CB-3 are the timed contact terminals.

The timer has two operating ranges; one low scale from 1/20 of a second to 3 seconds and the other scale from approximately 1/10 to 30 seconds. By means of two solenoid coils operated by a scale changer switch, it is possible to utilize either one of these two timing ranges. A small carbon resistor is sometimes used across the two solenoid coils to overcome the effects of residual magnetism and the solenoid assemblies which, in turn, will allow the release of the actuating arms when the push button is released. The following diagram is a schematic wiring diagram of the internal connections of the timer. The timer operates on the same principle as most synchronous timers inasmuch as the motor drives a disk or gear continually and by means of the solenoid coil action a friction clutch is applied against this moving surface. The length of exposure depends upon the position of the stationary clutch before engaging the moving disk driven by the motor. When the stationary

disk reaches the end of its travel it opens a set of timer contacts which in turn open the CB-1, and CB-3 terminal circuits.

MICRO TIMER - SCHEMATIC WIRING



ADJUSTMENT AND MAINTENANCE - The adjustment of the timer is accomplished by moving the bakelite clock to which the timed contacts are fastened. It will be seen that this timer block is held in place by two screws approximately 8-32 in size. By loosening the top screw slightly and fully loosening the lower screw, it is possible to shift the timer contact assembly to either foreshorten or lengthen the time until the stop on the stationary disk will open these contacts. By this means, the length of exposure can be increased or decreased as required. At no time is any form of lubricant to be used between the surfaces of the cork disk and the brass gear facings. It is suggested that adjustments to this timer should not be attempted unless absolutely necessary. The adjustment of time variations is comparatively simple but any other type of adjustment such as repositioning a gear mechanism or removing the solenoid assemblies, etc., will involve a considerable amount of time to readjust properly. In the event the solenoid coil should vibrate (called 60 cycle hum) in the majority of cases a quarter or a half turn on the Hexagon adjustment nut and spring assembly on the moving arm of the solenoid coil will completely eliminate the hum. This should be the limit of a serviceman's attempts to adjust this timer.

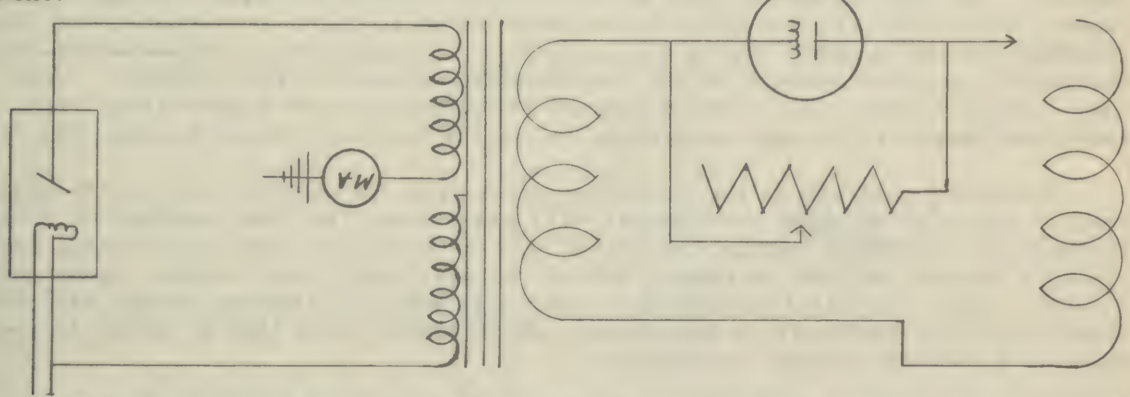
Various motors have been used in this timer from conventional two lead motors ordinarily employed on 8 or 10 inch fans to special 5-lead synchronous motors which had an inductive winding built into the motor to make it self-starting. The later type timers employ a large condenser as a starting device. The motors will rarely require any attention except the conventional lubricating rules and this lubricating need be done at very infrequent intervals.

SECTION XXIII

INVERSE REDUCER OR SUPPRESSORS

GENERAL - In a self-rectified x-ray apparatus, the inverse kilovoltage is always greater than the useful kilovoltage, the difference depending on the incoming line, x-ray unit regulation, and the load carried by the x-ray tube. Incorporation of an inverse reducer in the primary circuit serves to reduce the inverse kilovoltage to approximately the value of the useful kilovoltage. Reduction in the insulation and the high voltage parts-to-ground clearances is thus possible, permitting the use of a smaller and lighter container in which the high voltage generator and the x-ray tube are housed.

TUNGAR BULB TYPE - One type of inverse suppressor consists of a tungar bulb and a tapped resistance unit connected in parallel. The tungar bulb is a hot cathode argon-filled bulb of various ampere capacities. When the filaments of these bulbs are heated, electrons are thrown off into the gas and form a conducting path so that current will flow between the graphite electrode and the filament. Due to the nature and action of the electrons thrown off by the filament, the current can pass in only one direction through the tube, or from the filament to the graphite electrode. It cannot flow in the opposite direction to any appreciable extent; so when the A.C. reverses, the opposite half of the wave is shut off by the valve action of the bulb, and must pass through the resistance. The resistance unit is made of wire with zero temperature coefficient, which is wound on a core and cement covered. The tungar bulb must be used in conjunction with a resistance in parallel in order to provide for passage of exciting current to the high voltage transformer during the inverse half cycle. By introducing a proper amount of resistance into the circuit, the inverse kilovoltage is reduced to a chosen value. As the difference between the inverse and useful kilovoltage is greater on lines of poorer regulation, a greater amount of resistance must be used in order to cut down the inverse kilovoltage the required amount. Procedure for properly "balancing" the inverse reducer on a given line is outlined in detail in the installation directions for any particular equipment.



With the x-ray tube connected, nearly the entire load current passes through the tungar bulb during the useful half cycle. The current passing through the resistance unit during the inverse half cycle is the exciting current. An A.C. ammeter placed in series with the resistance unit will read approximately 1/2 the exciting current (the average of 0 amperes during the useful half cycle and exciting current amperes during the inverse half cycle). Appreciable heating of the portion of the resistance unit which is in the circuit is normal but not to the extent of overheating or burning out of the resistance unit.

To maintain the equipment in proper working order, the operator should be instructed to screw down the tungar bulb in its socket and to tighten the anode connector two or three times monthly. During periodic inspections, check the wiring in

the inverse reducer circuit and examine the filament of the tungar bulb for sagging after it has been lighted for several minutes. A moderate degree of sagging is not objectionable. However, if it becomes excessive, short-circuiting of the adjacent turns of the filament may take place requiring the replacement of the tungar bulb. Also observe the tungar bulb for gas flashes and smoke during the operation of the equipment. Make sure that a good contact is secured between the tungar bulb and the center contact in the socket. If called in connection with inverse reducer trouble, ascertain in addition, the condition of the resistance with respect to overheating. Note if solder inside the upper ferrule has melted away and the cement covering the wire has peeled off. Check the resistance for open circuit.

Should the filament of the tungar bulb burn out or should the tungar bulb become loosened in the socket, an alert operator will recognize that something is wrong with the equipment because the tungar bulb will not emit light and the voltmeter will indicate a large voltage drop on energizing the tube. If these manifestations of trouble are missed and the x-ray unit operated, the resistance in parallel with the tungar bulb will be forced to carry the load current during the useful half cycle and may burn out in a short time. At this stage the operator cannot help but notice that the equipment is inoperable because the milliammeter will not read.

A search for trouble may be instituted and the tungar bulb screwed down in the socket but the condition of the resistance unit which had in the meantime burned out may pass unnoticed. However, the operation of the equipment will not be restored to normal because of the open circuited resistance. The voltage drop will continue to be excessive and the overload circuit breaker may keep on opening. The explanation of this condition lies in the fact that a D.C. pulsating voltage is impressed on the transformer, the passage of the current on the inverse half cycle being suppressed. When A.C. voltage is impressed on an A.C. device such as the high voltage transformer, the current is limited by the reactance which is quite considerable, and the resistance which is low. When a pulsating D.C. is impressed on such a device the current is increased because of the considerable decrease in the reactance. Under this condition, excessive current through the primary of the high voltage transformer may damage it through overheating unless the overload circuit breaker acts.

Accidental reversal of the connecting wires from the control stand to the primary of the high voltage transformer will also cause the load current to flow through the resistance during the useful half of the cycle, thus overheating and probably burning out the resistance unless the overload circuit breaker opens the circuit. Once the resistance is open-circuited, a D.C. pulsating current will be impressed on the high voltage transformer, permitting a large flow of current to the primary of the high voltage transformer.

It may be pointed out that a gassy condition of, or inverse conduction in, the x-ray tube, as well as the high voltage leakage, will cause greater current flow through the inverse reducer resistance and may contribute to its failure. However, other abnormal manifestations in the operation of the unit will usually warn the operator that something is wrong with the equipment.

The cathode of the tungar bulb emits electrons which collide with and break up the argon atoms into electrons and positive ions. The conduction is largely dependent on the motion of the electrons and is for practical purposes unidirectional. If moderately gassy, the tungar bulb will conduct the current in both directions, and the inverse suppressor has no effect on the circuit. If excessively gassy or punctured, the tungar bulb will not conduct the current at all. Instead, the current will pass through the resistance on both useful and inverse half cycles.

Unless the operation is discontinued, the resistance unit will fail from overload.

In the event that the tungar bulb is satisfactory but the resistance unit is open-circuited, the resistance may be turned around and its good portion connected in the circuit. The value of the resistance should be approximately the same as was originally in the circuit.

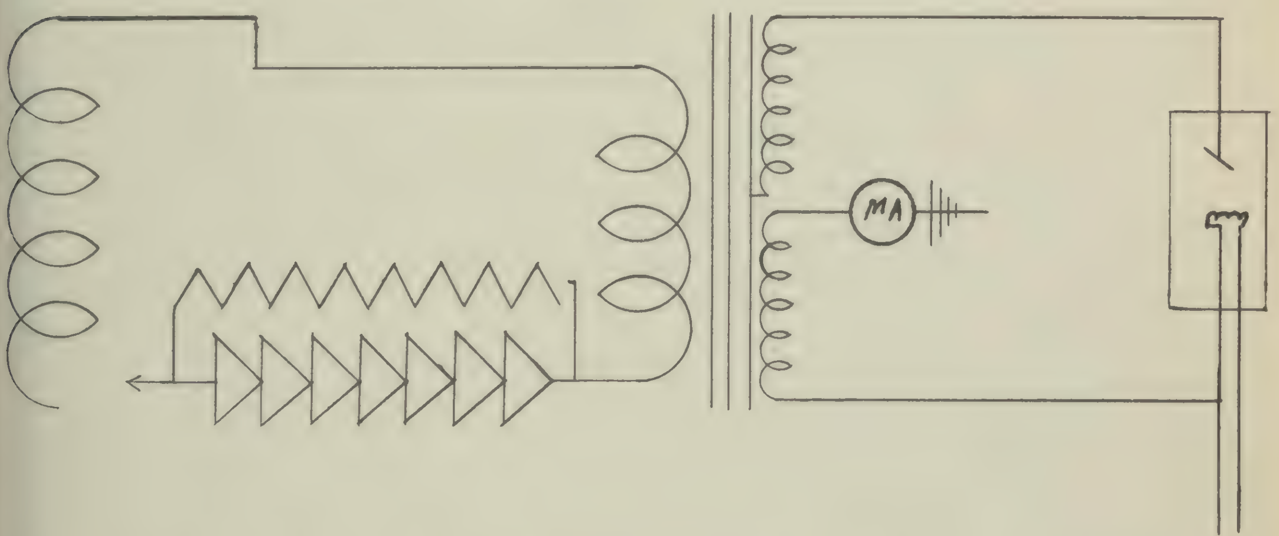
If the tungar bulb has failed, the equipment may temporarily be operated without it by short-circuiting the inverse reducer and operating the equipment at about 80 per cent of its maximum rated kilovoltage. To short circuit the reducer, connect together the two wires to the inverse reducer resistance unit.

COPPER OXIDE INVERSE SUPPRESSOR - Another type of inverse suppressor which is quite extensively used is one which uses a rectifier element made of a film of copper oxide on the surface of a copper disk, to act as a valve and pass current through it in only one direction.

This type of rectifier element provides a very convenient portable type of rectifier for use where small or moderate amounts of current are required. They are also very commonly used in radio sets and for the operation of certain D.C. signalling equipment, D.C. meters, battery charging, etc.

These rectifiers operate on a principle similar to that of the copper oxide lightning arrester, and the current can pass through them only in one direction, from the oxide to the metal plate.

These disks can be made in different sizes according to the current capacity desired, and a number of them can be stacked or clamped in series to build up the proper resistance according to the voltage which is to be used on them.



The function of both types of inverse suppressors in regard to equipment is the same, the only difference being in the rectifier element used in each.

SECTION XXIV

CALIBRATION OF X-RAY EQUIPMENT

CALIBRATION OF X-RAY EQUIPMENT

No installation of any apparatus can be considered complete unless a satisfactory and accurate calibration has been made. The calibration of the apparatus is the only means whereby the operator of the machine can utilize the apparatus to its greatest advantage to obtain the best results.

Calibration of x-ray equipment becomes the serviceman's function, primarily because it is impossible for the manufacturers of apparatus to anticipate the many varieties of line and power conditions which will be encountered by the apparatus in general use. Upon the final installation of an apparatus, the factory-made calibration may be found to vary considerably. Therefore, the serviceman must make certain that the factors indicated on the calibration charts are correct.

It is necessary that the operator be able to accurately determine and control the factors that produce the radiograph. In this way, the operator can: Avoid wasting film, obtain consistent results, use the same factors with any two machines, train new personnel easier, avoid x-ray tube overloading, safeguard insulation of cables and transformer, vary the standard technique to comply with the radiologist's particular requirements.

The four prime factors that produce the radiograph are Distance, Time, M.A., and Kilovoltage.

Distance is the measurement from the focal spot of the tube to the film. This factor can be controlled by the operator.

TIME - The lengths of exposures used for radiographic purposes are comparatively short. The need of accurate timing is necessary. The spin top test is a simple procedure whereby the actual impulses of current through the x-ray tube produce an image on the film. Thus, it is possible to accurately determine the length of the exposure. On self-rectification where the inverse half cycle of the high tension voltage is suppressed, only 60 impulses per second will flow through the tube. Therefore, on self-rectified equipment, in an exposure of a spinning top at 1/10 of a second, assuming the timer is correct, 6 shadows will appear on the film. On full-wave rectification, both alternations of the current are utilized. Therefore, 120 impulses would be impressed on the film in an exposure of one second. Thus, in exposure of a spinning top for 1/10 of a second, if more or less than 12 dots were shown on the film after development, it would indicate that the timer is in need of adjustment. The spin top method is limited to exposures not exceeding 1/5 of a second. It is assumed that if a timer is accurate for exposures of 1/5 second (24 dots on full-wave, 12 dots on half-wave, 60 cycle), exposures in excess of 1/5 second will be accurate enough for all practical purposes.

MILLIAMPERAGE - Milliamperage can be indicated as that current which is flowing through the x-ray tube. The amount of M.A. flowing through the tube is a function of the heat of the filament of the tube itself. The heat of the filament provides the electrons, which in turn determine the amount of current that will flow from the cathode to the anode of the tube. This current registers on the M.A. meter on the control panel. This meter is generally connected in the mid-points of the high tension secondaries, and it will not register until high tension is flowing. The total exposure time allowable on x-ray tubes is governed by the size of the focal spot in use and the type of rectification in relation to the amount of kilovoltage and milliamperage flowing through the tube. On short, heavy exposures the M.A. meter does not have time to register full value of load. Most commercial meters require an exposure of at least three-fourths of a second before the meter can be read. For this reason, a meter to determine the amount of M.A. flowing through the tube during short time exposures is necessary. A meter, known as a

Ballistic M.A. or M.A. second meter is utilized. This meter registers the product of time multiplied by the milliamperage and when the timer is accurate, the M.A. flowing through the tube can thus be determined.

For example, when the Ballistic M.A. meter reads 10 M.A.S., and the exposure made utilizing an accurate timer set for an exposure of 1/10 second, it is obvious that 100 M.A. were flowing through the tube. With an accurate timer set for an exposure of 1/20 second and the Ballistic meter reads 10 M.A.S., it is obvious that 200 M.A. were flowing through the tube.

KILOVOLTAGE - Kilovoltage is the factor most affected by incoming line voltage variations. Since the penetrating power of x-rays is controlled by their wave length (the shorter the x-rays, the greater their penetrating power), the kilovoltage across the tube *under load conditions* is of major importance. It is a well known fact that when a load is placed across power lines, a certain amount of voltage drop must be anticipated. This voltage drop will be reflected in kilovoltage drop across the x-ray tube. True kilovoltage under load conditions can be determined in several ways. Manufacturers of x-ray equipment have various means for determining the true kilovoltage under load. The instructions supplied with all apparatus cover this phase of calibration completely. These instructions, if adhered to, will permit an accurate kilovoltage calibration for use on the machine to be operated.

True kilovoltage determination under load is obtained in different manners by the various manufacturers. A simple and quite common method is by means of a voltmeter, placed in parallel across the primary of the high tension transformer. This voltmeter is placed *before* the contactor device in order that this voltmeter can be read before the high tension primary circuit is closed. Frequently, these voltmeters are calibrated with relation to the type of transformer and control they are to be used with. As a result of such calibration, a new meter face is made and instead of indicating the actual primary volts supplied the transformer, the new meter scale is drawn to indicate the Kilovolt output of the unit at various input voltages. Thus, the term, kilovolt meters.

A pre-reading kilovoltmeter permits a reading after compensation for line drop under load has been taken into consideration, and before the exposure is completed. Milliamperage is considered the load of an x-ray machine. A greater line drop will be encountered using 100 M.A. than 5 M.A. For example, assume a meter may correctly indicate a value of 70 K.V. at 5 M.A. when the load is impressed on the tube. As this 5 M.A. setting constitutes a light load, even for a poor line, there will be no appreciable line drop. However, 100 M.A. would constitute a considerable load; therefore a considerable line drop should be anticipated. Thus, the kilovolt meter set to read 70 K.V. before the load is applied would actually read less than 70 K.V. when 100 M.A. is used. To overcome this condition, various means of correcting the kilovolt meter reading are used.

A common method used to overcome the condition described above is to induce a bucking winding coil plus an adjustable resistance or rheostat into the voltmeter circuit. This bucking voltage can be set, by means of a dial on the control stand, that at various milliamperage loads across the tube, the kilovolt meter reading can be increased or decreased as the case may be. Thus, with a heavy milliamperage load across the tube, more bucking winding voltage is impressed across the meter circuit and the meter will read a correspondingly lower value.

Another type of kilovolt meter is known as a "load-on" kilovolt meter, and, as its name implies, it is intended to be read with the load impressed across the tube.

This meter has an arbitrary scale compensated for the ratio of high tension transformer (primary to secondary), and is calibrated for the voltage drop that will take place in the circuit of the x-ray machine itself. This type of kilovolt meter should be used on low milliamperage apparatus only (30 M.A. or less). At low values, the load can be kept on the tube long enough for the kilovolt meter reading to be made.

Direct reading kilovolt dials mounted on the knobs of the auto transformer controls is another arrangement for determining true kilovoltage under load. The means of maintaining true kilovoltage determination by these dials must be supplemented by some device to put additional voltage into the high tension primary circuit to compensate for the voltage loss under load conditions.

There are other means used by manufacturers to determine true kilovoltage under various load conditions. One method is to use what is known as button control. This system employs a series of numbered steps on the kilovoltage control to permit more or less turns of the autotransformer to be put into the high tension circuit to compensate for the various milliamperage load drops across the primary of the high tension. For example, in the event that 60 K.V. and 5 M.A. were to be used, the kilovolt control might be set at button 24. If 60 K.V. at 100 M.A. were desired, it might be necessary to set the kilovolt control up to button 28. All these methods are practical and serve the purpose of enabling the operator to determine true kilovoltage *under load.* The manufacturers' instructions explain the methods to be used that will enable the serviceman to satisfactorily and accurately calibrate the equipment in order that the actual kilovoltage will be known under the various milliamperage loads.

Some shockproof and all non-shockproof equipment can be calibrated by means of a sphere-gap. This device employs the principle of a spark gap to indicate when the air between the two points of the gap becomes ionized. A sparkover results because of a potential difference between the two points. The sharper the points, the easier the air between them becomes ionized. Therefore, a gap employing needle points under certain conditions would spark over at approximately 6 inches, a gap using 3-inch spheres, would spark over at a distance of approximately 1-3/4 inches. The reason for the difference in sparking distances is that, with needle points, the electrons are more concentrated. On the spheres, which represent a much larger surface area, the electrons are dissipated over a greater area and therefore do not fly over to the terminal of the opposite potential so readily. The sphere-gaps employ various types of calibrated scales to register the K.V.P. at which the sparkover occurred. Weaknesses of these devices are temperature, barometric pressure, and humidity; all cause variations in the readings obtained. Variations in the operation of this device also cause sphere-gap readings to be inaccurate.

DENSIMETER OR COMPARATIVE DENSITY DEVICES - These devices are used to determine true kilovoltage under load, by means of radiographic comparison. A certain density of an aluminum disk, or ladder arrangement is obtained with three known factors (K.V., M.A., and time). If this density is compared with another radiograph of the same testing device having equal densities, it is apparent that the two densities were obtained using similar or equivalent exposure values. Assume two radiographs are made, one using 10 M.A. for one second at 60 K.V.P. and the other using 100 M.A. for 1/10 second at 60 K.V.P. Since both exposures are similar (10 M.A.S. at 60 K.V.P.), the densities of these two films should be identical.

The devices used for this method of calibration are known under different names and will be found in various shapes or forms.

The principle of operation is that standard exposures are made in which the three factors (Time, M.A. and K.V.P.) are known. A set of these films made with various exposure values, serve as a standard.

To calibrate a unit, a series of films are made under conditions where two factors, time and M.A., are known. By comparing the densities of these films with that of the standard set, made under similar conditions with the exception of the kilovoltage, it can be seen that any variation in the density can be attributed to the third (unknown) factor, kilovoltage. In instances where the densities agree, it is apparent that these densities were made with the same or equivalent exposure values. Since two values are known (M.A. and time), variations of the density can be accounted for considering the kilovoltage.

Never fail to make a complete, correct calibration upon finishing an installation. The calibration is the only means the operator has of determining the exposure factors. Should the calibration be inaccurate, the radiographs will not be accurate nor consistent. It is impossible to outline the various types of line conditions and line faults that will be encountered. An extremely good line is a rarity. Most power lines encountered will have voltage variations, varying from 2 to 5% *without* load. Power transformer size, length and size of the incoming wire, etc., will contribute to variations between different installations.

SECTION XXV

BUCKY

POTTER BUCKY DIAPHRAGMS - CONSTRUCTION - The Potter Bucky Diaphragm is the most efficient accessory for the elimination of secondary radiation. The percentage of the secondary radiation absorbed by the Potter Bucky Diaphragm is determined by the ratio of the grid and the number of strips per inch. The Bucky grid is composed of a series of lead strips, approximately 0.005 inch in thickness, placed on edge and spaced apart by thin wood strips or similar filler material. The primary radiation passes between the lead strips and reaches the film. Secondary radiation propagated at an angle to the primary beam strikes into the vertical strips of lead forming the walls of the transparent slots and is absorbed. The distance between the leads strips determined by the thickness of the filler material, governs the width of the slot. GRID RATIO IS THE RATIO OF THE HEIGHT OF THE SLOT TO THE WIDTH OF THE SLOT. In an 8 to 1 ratio Bucky, the slots are tall and narrow. The radiation clean-up is efficient due to the fact that the only secondary rays that can penetrate through the grid are those traveling parallel to the primary radiation.

The higher the ratio, the more efficient is the absorbtion of secondary radiation.

GRID RATIO AND RADIUS - All Potter Bucky Diaphragms are built to operate at a certain target-to-film distance. Since the x-radiation is divergent, the grid must be built so that the lead strips nearest the edge are angulated to receive the divergent radiation. Whenever possible, the x-ray tube should be centered directly over the mid-line of the Potter Bucky Diaphragm, and the target-film distance should conform as closely as possible to the grid divergence. A high ratio grid, particularly one of 40 inch divergence, must be centered very critically. A Bucky to be used in a radiographic table is, 6 to 1 to 8 to 1 ratio. Whenever the tube is improperly centered over the grid, in relation to the mid-line of the table, a general overall reduction in density of the radiograph will be noted. The amount of density loss will be proportional to the distance "off center" (see illustration). If a stereoshift is made *across the table*, transverse to the grid strips, and the shift is not carefully divided to be equidistant from the mid-line, one stereo will be lighter than the other. This phenomenon will be more marked when working with a high ratio Bucky. If the x-ray tube is centered over the center of the grid, but at a target-film distance too great or too small, a cut-off or loss in density will be noted on both sides of the film. These conditions become more critical as the grid ratio is increased. GRID RATIO IS A COMPROMISE BETWEEN EFFICIENCY OF SECONDARY RADIATION CLEAN-UP AND FLEXIBILITY OF DISTANCE AND CENTERING.

THE NECESSARY INCREASE IN EXPOSURE TIME - Whenever a Potter Bucky Diaphragm is employed, it is necessary to increase the total exposure to compensate for the secondary radiation absorbed by the grid (The secondary rays would otherwise have fogged the film and caused a certain degree of blackening) and for a certain small quantity of primary radiation absorbed by the lead strips in the grid. (A properly constructed Bucky grid will transmit at least 87% of the primary radiation striking its upper surface). It is usually necessary to use at least three times the exposure required in a non-Bucky technique when using a Potter Bucky Diaphragm. This ratio of non-Bucky to Bucky exposure may vary between two and four and one half times, depending upon the construction of the grid and the quantity of secondary radiation generated within the part and absorbed by the grid.

GRID LINE FORMATION - The Potter Bucky Diaphragm must be moved through the radiation beam during any given exposure in order to prevent the formation of grid shadow on the film. There are several problems involved in the formation of grid lines as follows:

The Bucky Grid must travel smoothly. If it should pause momentarily during the

travel, grid lines would result. The drive mechanism of a good Potter Bucky Diaphragm is intended to provide a smooth motion at a controllable speed.

The exposure must occur during grid travel. If the grid starts after the exposure has started, or if the grid stops before the exposure is completed, grid lines will result. A modern Potter Bucky Diaphragm is equipped with electrical contacts which may be wired through the Radiographic Timer circuit to prevent the exposure occurring, unless the Bucky is in motion.

Occasionally, it is desired to hook up a high speed Bucky to operate with an impulse timer. An impulse timer often has an appreciable time lag from the moment that the magnetic clutch is released until the exposure starts. Therefore, it is often necessary to provide a special Bucky hook-up in which the Bucky is released simultaneously with the release of the impulse timer clutch. In order to make these circuits operate properly, it is usually necessary to insert a time delay in the Bucky magnet release circuit to delay the release of the Bucky in order to insure that the grid will be traveling during the actual x-ray exposure.

On all short exposures, *the Bucky must travel at a non-synchronous speed* to prevent the grid shadows which result from a synchronization between the moving Bucky grid and the flashing x-ray output. Grid formation due to this cause can vary from a broad "corduroy" gridding whose characteristic is a broad white line with a narrow "dark line" down to a true Bucky grid pattern which will be evident when the grid is moving in absolute synchronization.

It is possible to calibrate a Potter Bucky Diaphragm so that the grid speed controller can be set on a non-synchronous position prior to each exposure. It is always advisable to operate a Potter Bucky Diaphragm in conjunction with a Bucky-Timer interlock in which the Bucky timing contacts serve as a push button for the synchronous motor driven timer. With this type of circuit hookup the Potter Bucky speed controller can be set at a non-synchronous point and the exposure time controlled by the timer. In this way, grid formations will be avoided.

WHEN THE BUCKY GRID TRAVELS SMOOTHLY AT A NON-SYNCHRONOUS SPEED AND THE EXPOSURE OCCURS DURING GRID TRAVEL THE LIMIT OF HIGH SPEED GRID-FREE BUCKY RADIOGRAPHY WILL DEPEND UPON - The number of grid lines per inch; the forward speed of the grid; the generator wave form.

Due to variations in these three problems, the minimum exposure time that can be used with grid-free radiography may vary from as much as 3/4 seconds down to as little as 1/30 second.

THE BUCKY DESIGN - The perfect bucky will have as high a ratio as possible in keeping with the application for which the Bucky is intended. The divergence of radius of the grid will be set to conform to the target film distance in the middle of the normal working range for that Bucky. The perfect Bucky will pass as much of the primary radiation as possible.

The grid absorption (percentage of primary beam transmission) is determined by the amount of lead per inch. Each lead strip must be at least 0.003 inch thick in order to stop the secondary radiation. Most of the old type Buckys were constructed with lead strips of 0.005 inch. A Bucky with the 0.005 inch lead thickness, having 30 lines (lead strips) per inch will transmit eighty-seven per cent of the primary beam. Any increase in the number of lines per inch, without a proportionate decrease in the thickness of each individual strip, would result in an increase of the primary beam absorption which would require a considerable increase in the exposure.

The ideal Bucky will have approximately 50 lines per inch with 0.003 inch lead strip thickness and 87% primary beam transmission.

Whenever the number of lines per inch is increased, the grid ratio would also be increased unless the total thickness of the grid (i.e., the height of the lead strips which determine the height of the slot) was reduced. If more than 50 lines per inch were used with a grid ratio less than 6 to 1, the resulting grid would be unduly fragile and might warp or break during use. The maximum number of lines per inch, therefore, is determined by the required mechanical strength of the grid; the minimum tolerance of lead strip thickness (0.003 inch); the goal of at least 87% primary beam transmission.

NON-SYNCHRONOUS CALIBRATION - It is of great value to have a Potter Bucky Diaphragm calibrated at the factory to indicate the location of the non-synchronous positions. This eliminates testing in the field and allows the operator to take full advantage of the high speed non-synchronous settings for fast Bucky radiography. The introduction of non-synchronous calibration gives the manufacturer one more problem in that the Buckys supplied must be calibrated to conform with the frequency of the electrical supply (50 or 60 cycle).

THE FLARSHEIM TEST - GENERAL PURPOSE - To provide a method of diagnosing faults in the grid motion; accuracy of timing and adjustment of exposure contacts of a Potter Bucky Diaphragm; to provide a method of indicating the relation of the actual x-ray exposure to the movement of the Potter Bucky Diaphragm.

PREPARATION - Remove the table top or Bucky panel to expose one (upper) surface of the grid. Prepare a "Flarsheim Tester" by putting a clean narrow (0.5 mm approximately) slit in a 1/8" sheet of lead, approximately 8 x 12 inches in size. The slit should be cut from the center of the 12" edge into the lead sheet parallel to the 8" edge and should extend about 2/3 of the way across the sheet. This will allow the lead sheet to hang together without external reinforcement.

In making a Flarsheim Test do not shoot through the grid. A small film is preferred. Use a cardboard holder or a film wrapped in black paper. It must be remembered that approximately 20 times the screen exposure must be given to achieve the same density without screens. Exposure holders are easy to handle. With adhesive tape or Scotch tape, fasten the film in paper or an exposure holder firmly onto the surface of the Bucky grid, *exposure side up ---- away from the grid.* The film must be fastened securely so that it moves with the grid. Suspend the "Flarsheim Tester" (lead sheet) over the film parallel to its surface, and just far enough from it to allow the grid and film to pass freely underneath the lead sheet.

THE LEAD SHEET REMAINS STATIONARY: THE FILM MOVES WITH THE GRID DURING BUCKY MOTION - The lead sheet should completely protect the film and allow primary radiation to expose the film through the narrow slit only.

The film and lead sheet should be arranged so that the lead slit bisects the 7" dimension on the film when the grid is midway in its travel.

The 7" dimension of the film is turned at right angles to the lead slit and the grid motion is at right angles to the lead slit.

Center the x-ray tube over the lead slit at approximately a ten inch distance for the non-screen exposures.

By making an x-ray exposure during grid motion, each impulse can be made to

imprint on the film in much the same manner as when using a spin top.

The sequence of exposure should be as follows: Cock the Bucky and make an exposure with the grid standing still. The subsequent dark line on the film will indicate the "start" position of the grid. Make a regular "Bucky" exposure with desired "time" setting on timer and desired "speed" setting on Bucky timing dial. Grid is to move in the usual way during exposure. Each impulse imprints through the lead slit onto the moving film. When the grid has come to rest, make a third exposure to imprint the "stop" position of the grid.

It is good practice to place some small object (such as a screw) across the lead slit during the first exposure. This will break the start line and indicate the direction of grid motion (identify the start position).

In practice, several tests of different Bucky speeds and exposure time intervals can be made on one film by covering subsequent portions of the lead slit during each exposure. A slit only 1/2" long will print a wide enough test strip to allow easy diagnosis.

When several tests are made on one film, it is suggested that "start" and "stop" positions be imprinted for each individual test, since either the film or the lead plate may become slightly dislodged during repeated movements of the Bucky grid.

A second type of Flarsheim test gives excellent data regarding the acceleration, smoothness of motion and de-acceleration of the Bucky grid. If the grid starts slowly, the contacts may close and start the exposure before the grid comes up to full speed. If defective mechanism is present the grid may move unevenly or stop momentarily during the exposure. If de-acceleration starts before the exposure is complete, the grid might slow down to a synchronous speed momentarily and produce grid lines. Before the Flarsheim Placement Test can be properly diagnosed this Flarsheim Motion Test must be made at various grid speeds to determine the limits of the *Full Speed and Smooth Travel Distance* during which the exposure must be made.

The procedure for the *Flarsheim Motion Test* is as follows: Arrange the lead plate and film in the usual manner and cock the grid; set a long exposure (2-3 seconds) on the *Timer*; set the grid dial to indicate the speed of motion desired, and start the exposure with the grid standing still. Trip the grid manually during the exposure so that the exposure continues until after the grid has come to rest.

DIAGNOSING A FLARSHEIM PLACEMENT TEST

FAULTY BUCKY CONTACTS - When the Bucky contacts serve as a "push button" for the motor-driven synchronous timer, (Bucky-Timer interlock) the exposure should not start before the grid has come up to full speed. If the first contact of the Bucky timing device is faulty, the exposure may start too soon. In the Flarsheim Placement Test, the distance between the Start line (cocked position) and the first x-ray impulse should be sufficient to include the "acceleration period" of the grid. If the Exposure (timer) is somewhat less than the Bucky setting, the timer will stop the exposure before the last Bucky contact opens. This is the usual procedure and is right.

If the Exposure (Timer) were set for an interval longer than the Bucky setting, the last Bucky contact should terminate the exposure before the grid has begun to de-accelerate.

THE EXPOSURE MUST OCCUR DURING GRID MOTION.

ADJUSTING THE TIME DELAY ON AN IGNITRON TIMER - HIGH SPEED BUCKY HOOKUP - When using the Ignitron Timer (1/5 - 1/30 second) the circuit hookup is such that the trigger switch energizes the Ignitron Timer clutch and the Bucky release simultaneously. There is a known 1/10 second delay in the Ignitron Timer. It is necessary to insert a time delay in the B.M.C. lead to the Bucky in order to set the Bucky off a moment late and insure that it will still be moving when the exposure is made.

This delay may be inserted by wiring SG relays in series in this lead (BMC) or by the use of an adjustable electrical time delay relay.

With a short interval, non-synchronous, time setting on the Bucky dial and the proposed exposure set on the Ignitron Timer, a Flarsheim Placement Test should be made and the time delay relay adjusted so that the last impulse is complete before the grid starts to slow down. This adjustment should be made at the fastest non-synchronous grid speed and the longest exposure to be used at that grid speed. The time delay must not be excessive, or else on the 1/5 second exposures at a slower grid speed, the exposure may start before the grid comes up to speed. The time delay in the Ignitron Timer is a constant. The time delay inserted in the BMC lead will be a constant. The grid speed and exposure time are variables.

Adjust the time delay (BMC) as follows: If the exposure continues after the grid slows down, increase the time delay; if the exposure starts before the grid starts, *decrease* the time delay.

The one time delay value must apply to every exposure from 1/5 second to the longest exposure permitted at the fastest non-synchronous grid speed (usually 1/15 second with Bucky set at the 1/10 non-synchronous position).

This time delay will function on every Bucky exposure and will not interfere on exposures over 1/5 second in which the Bucky timing contacts are used.

CONCLUSIONS - The Flarsheim Test provides an accurate means of diagnosing Bucky faults and adjusting time delay mechanisms for High Speed Bucky Radiography.

FIXED AND MOVING TYPE GRIDS FOR RADIOGRAPHY AND FLUOROSCOPY - The principles underlying the construction and use of the Bucky Diaphragm are generally known. However, from time to time new applications of these principles are developed. One such development being a newer type of fixed grid, more commonly referred to as the Wafer Grid.

At times considerable confusion has existed as regards the relative uses of the familiar moving grid type of Bucky Diaphragm known as the Potter Bucky Diaphragm and this latest fixed grid. It is the purpose of this outline to point out the circumstances under which each of these grids are particularly useful.

The first Bucky Diaphragms used were fixed or stationary grids. These grids were in some instances constructed of thick wood strips and very coarse lead strips. Since it was used in a fixed position, the coarse construction caused heavy grid lines that made its use inadvisable where a study of minute structure was necessary. The construction was improved to some extent by using thinner wood and lead strips, but even at best the fixed grid as originally conceived was never considered of great value. For radiography, the only solution to the grid line problem was to move the grid during the exposure. By so doing, and with proper construction and timing, it was possible to so distribute the image of the grids that objectionable grid shadows on the film were not visible.

The development of the Potter Bucky Diaphragm to its present state of perfection is considered one of the really great advances in the science of radiography, and because of its efficiency in greatly improving the general quality of radiographs of certain area, it is considered well nigh indispensable if the very highest quality of radiographic work is to be obtained.

Despite the many advantages of a properly designed Potter Bucky Diaphragm, it does have certain limitations. Due to the necessary mechanism for moving the grid and other factors too numerous to mention, unusually short exposures without objectionable grid lines have always been a problem. To date, 1/10 second is the shortest exposure timer generally used with the moving grid. Some diaphragms have been constructed for experimental work for use at a time of exposure as short as 1/20 of one second, but to date Potter Bucky Diaphragms of this type are not considered practical.

It therefore might be stated that in so far as routine work is concerned, the shortest practical exposure time with the Potter Bucky Diaphragm is seldom shorter then 1/2 second unless grid lines on the film are considered as not being objectionable. The necessary size and weight of the Potter Bucky Diaphragm is such that considerable difficulty is encountered when attempting to make use of it as a portable unit or for bedside work. The fact also that the Potter Bucky Diaphragm requires accurate centering further complicates its use in portable and bedside work.

Virtually all Potter Bucky Diaphragms are designed to be used within relatively narrow limits in so far as the focal-film distance is concerned. At the present time, the focal-film distance for most Bucky Diaphragms is either 30" by 40". Distances other than those mentioned can, of course, be employed, but if such is done, a variation in density of the film will occur, particularly when 14 by 17 films are being used. This variation in density is of course very much more pronounced toward the outer margin of the film, crosswise the grid strips. A considerable variation in distance may be made with the Potter Bucky Diaphragm without materially affecting the radiographic density in the immediate center of the film.

However, for all general work and aside from the above mentioned limitations, the Potter Bucky Diaphragm, either the curved type or the flat type, is to be recommended.

Recently, however, there has been placed on the market a fixed or stationary grid that overcomes many of the objections to the older type stationary grid. This new grid is knows as the Schonader, Lysholm, or more commonly, the Wafer grid.

The Wafer grid is not to be recommended for all types of work. However, it does fill a particular field which is outside that of the Potter Bucky Diaphragm.

This Wafer grid is constructed of very thin strips, much thinner than ever used before. So thin are the lead strips and so close together are they placed that the grid lines are not objectionable for many types of work. As a matter of fact, they are scarcely visible at the ordinary viewing distances.

The Wafer grid is approximately 1/4 of an inch in thickness and is made in various sizes. It is considerably lighter in weight than the average cassette of the same size. The direction of assembly of the grid strips is indicated so that the grid lines may be made to appear either crosswise or lengthwise the film as desired. No attempt is made to position the grid strips to make them centered to the tube. In other words, the grid strips are at all times perpendicular to the film. Since the Wafer grid is stationary, it may be used for exposures of any

length. This makes it especially adaptable to Hi-speed work such as gastro-intestinal studies, air-injection studies of the skull, esophageal studies, heart and chest radiographs. A word about the chest will indicate some of the possibilities of this type of grid. In lateral chest work, high voltages are oftentimes necessary if short exposures to prevent motion are made. A long target-film distance should be used to provide good detail. This results in a grey film with poor delineation of bone structure and consequent loss of diagnostic value. The problem of penetrating the heart and retaining sufficient contrast to visualize lung structure is very difficult. The Wafer grid makes this possible. Even in P.A. views of the chest, its use is advisable when areas of dense consolidation such as fluid, etc., are encountered.

Its use for lateral and oblique views of the heart make possible a type of work very difficult to duplicate otherwise.

The ability to use the stationary grid for rapid exposures makes it very useful for emergency radiography. Its extremely light weight and very thin construction makes its use easy without removing the patient from the stretcher cart.

The thin construction of the Wafer grid makes its use valuable in studies of the body where the object film distance is especially important. Perhaps the most notable of these studies is in gastro-intestinal radiography. The additional 1/4 of an inch object-film distance caused by the Wafer grid thickness is negligible. As a result, films with a high degree of contrast can be produced without sacrifice of sharpness of detail.

Its light weight and small space required makes the Wafer grid a feasible thing for use in certain types of portable and bedside work. It can be carried with the cassette to the bedside and since it is very thin can be slipped under the patient with the cassette with a minimum of effort on the part of both the technician and patient. One of the biggest problems in any hospital is radiography of the hip and spine at the bedside. The Wafer grid aids materially in solving this problem.

The Wafer grid has certain disadvantages that will prevent it from ever replacing the Potter Bucky Diaphragm or moving grid.

The presence of grid lines on the film makes it inadvisable for use where minute detail is to be studied. In gross fracture, for instance, these grid lines are ordinarily not objectionable, but for bone study in minute lesions, its use is not to be advised.

The fact that the grid strips are not tilted toward the edge, limits the area that may be successfully covered at any given focal-film distance.

At distances of 25 or 30 inches, areas not larger than 8 by 10 or 10 by 12 should be studied. Larger areas may be covered only with increased focal-film distance. A 4-foot distance being necessary to successfully cover an area 17 by 17 inches.

The Wafer grid may be used for fluoroscopy where the additional voltage required can be used. It is not so well adapted to this work as those grids especially constructed for fluoroscopy but can be used for fluoroscopic work if the regular fluoroscopic grid is not available.

BUCKY

SERVICE NOTES ON BUCKY DIAPHRAGMS

OIL LEAK - If the Bucky pump tends to leak oil, tighten the packing around either the piston rod or timing control rod. Care must be used that these are not tightened too much to avoid excessive turning or movement pressure.

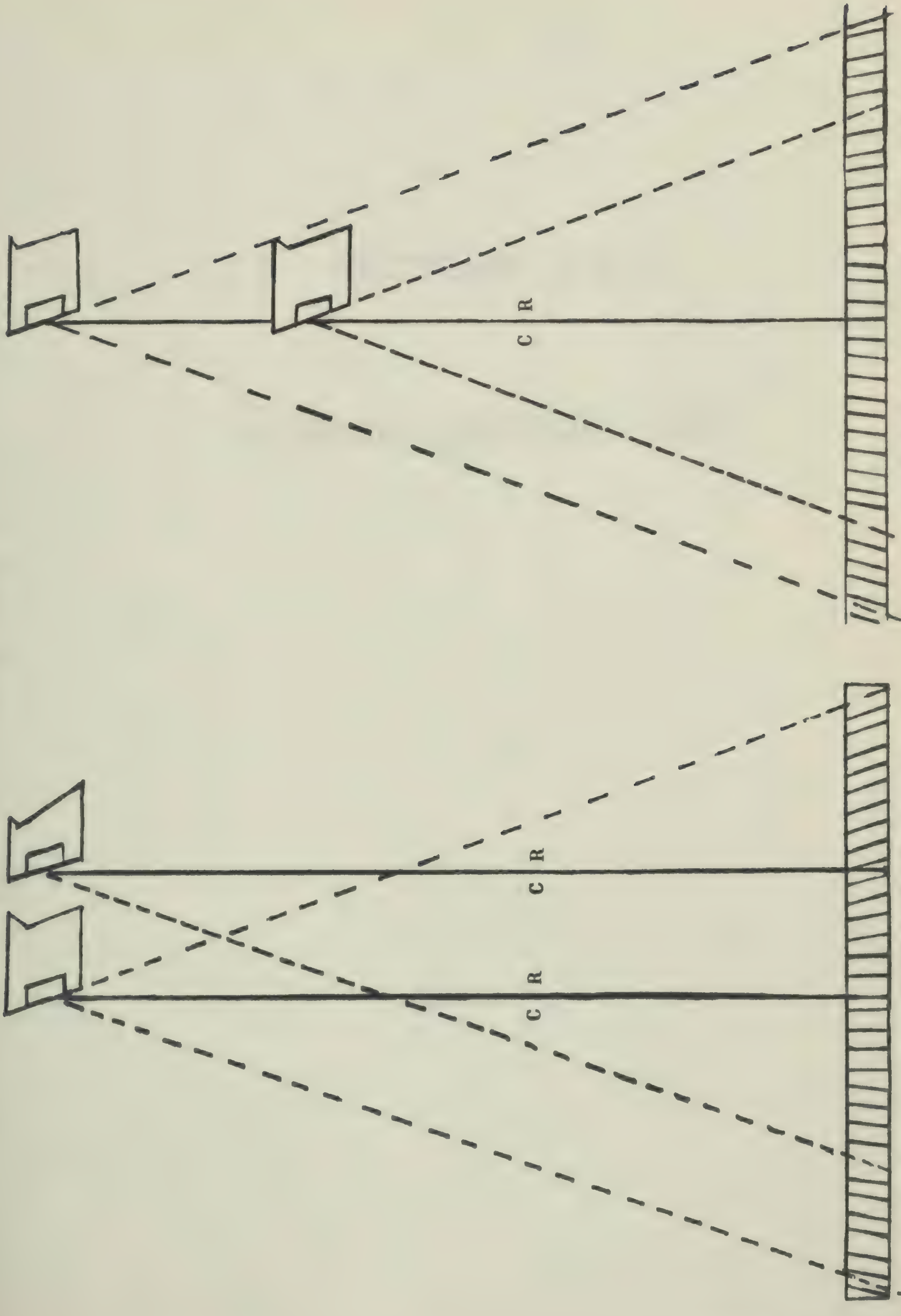
ADDING OIL TO BUCKY PUMP - Some Bucky pumps have a filling screw through which oil may be added. High grade oil is to be used whenever the pump must be refilled or oil added. To add oil set the Bucky in such a position that the filling screw on the pump is up, so that oil will not flow out of it due to gravity when the filling screw is taken out. By means of a curved tube and funnel, oil can be added to the pump. Add oil until it is completely filled up. During the filling process, work the piston of the pump back and forth very slowly in order to work out any possible occuluded air.

SWITCH ADJUSTMENTS - On the x-ray switch itself there are three adjustments of the effective travel of the Bucky, the effective travel being that part of the travel during which the x-ray contacts are made. The bakelite block which is rigidly mounted on the grid frame and operates the switch can be moved somewhat for switch adjustment. The switch itself has slotted holes in the base, through which some adjustment can be provided in mounting it in place. Mounted on the upper contacts of the switch itself is a bakelite block which determines the point at which the switch "kicks off". These adjustments are all made and so synchronized in such a way that the grid is directly on center when it is in the middle of the effective travel. Also, on re-cocking, the switch must be set so that the upper lead snaps into the cocked position at exactly the same time that the catch which holds the grid frame in the cocked position snaps into place. Presently, on all Standard and High Speed Buckys, the switch is set so that the pre-travel, that is the time the grid travels from the normal cocked position to the point where the x-ray contacts just make, is 3/16". On the Standard Speed Buckys, the travel is 1-7/16". On the High Speed Buckys the effective travel is 8/10". However, on other types of Bucky this travel will be different and may change at any time on any particular line of Buckys as the case may require.

MAGNETIC RELEASE COIL - If the Bucky fails to release with the electrical control, look for trouble then in the magnetic release circuit. Either the magnetic release bobbin or the series switch mounted either on the bobbin or on the terminal board, may be causing trouble. Other possibilities are loose connections either at the connection plug or on the terminal board.

TIMING - On any Bucky the calibrations below 1 sec. are in error not more than 3 to 5% for ordinary changes in ambient room temperature, that is over a range from 60 to 90 degrees F. However, on the longer exposures up to 20 seconds, the variation may be, under extreme conditions, as much as 15%, running slow in cold temperatures and fast in warm temperatures.

FOCUSED GRIDS

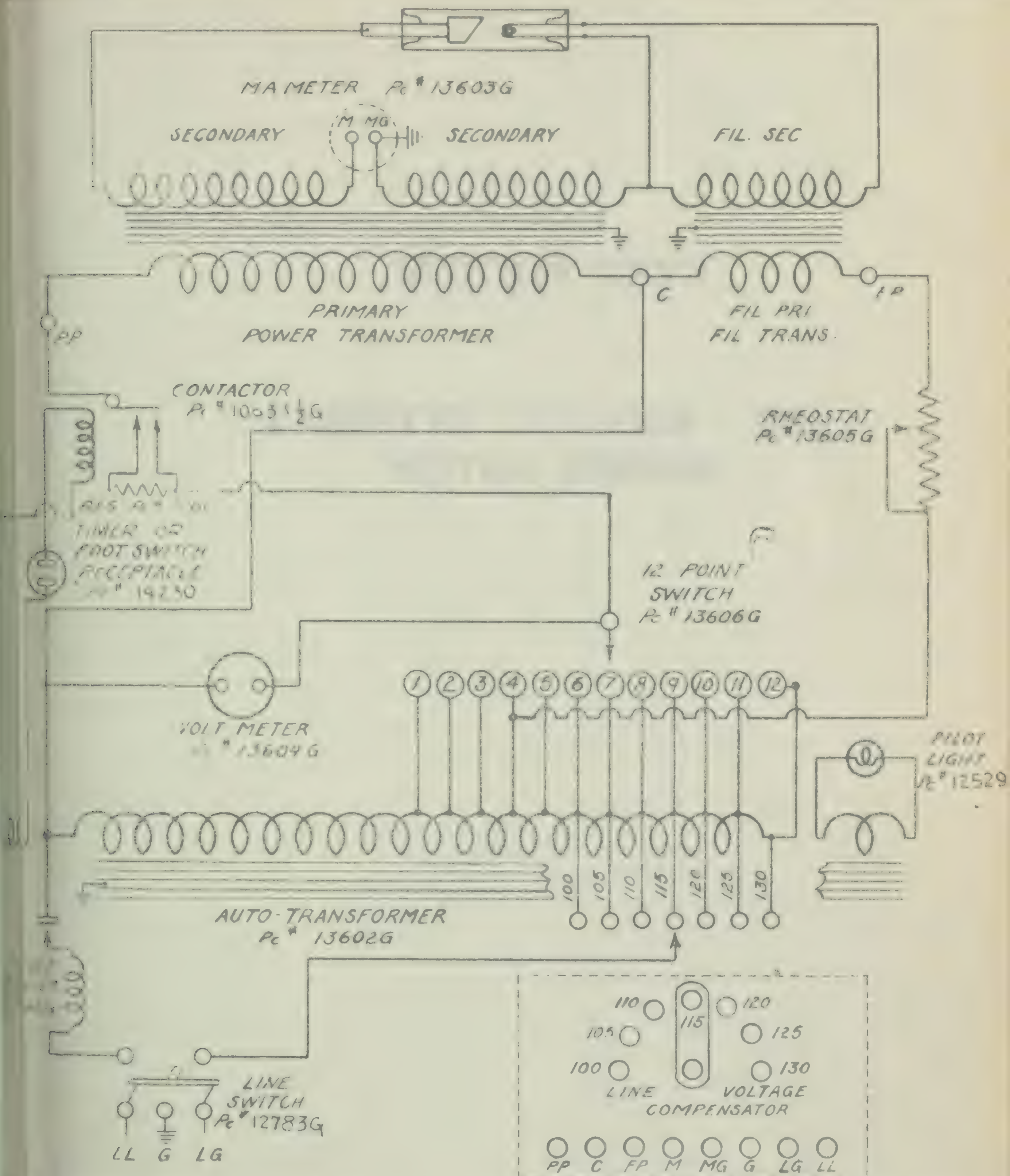


IMPROPER F.F.D. CAUSING "CUT-OFF"

IMPROPER CENTERING CAUSING "CUT-OFF"

SECTION XXVI

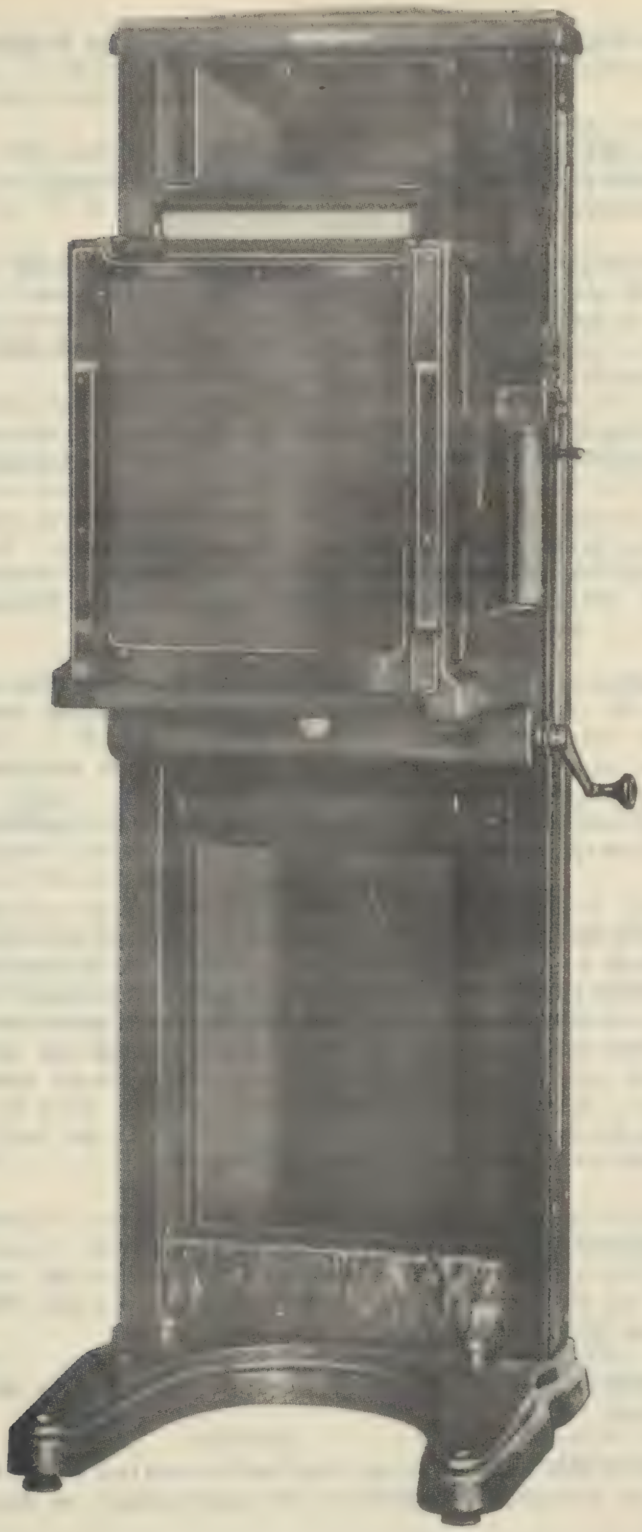
FISHER DENTAL UNIT



WIRING DIAGRAM FOR
ARMY DENTAL X-RAY UNIT

SECTION XXVII

CASSETTE CHANGER - G.E. MOTOR DRIVEN



G.E. MOTOR-DRIVEN CASSETTE CHANGER

GENERAL - The G.E. Motor-Driven Cassette Changer is shipped from the factory dismantled into the following major assemblies.

The base casting Fig. 1, Illustration #1.
The upright structure Fig. 2, Illustration #1.
The housing for the changing and raising mechanism, Fig. 3, Illustration #1.

The cassette changer is furnished arranged for right-hand operation of the raising and lowering mechanism. The cassettes can be inserted from either side. If it is desirable to have the raising mechanism arranged for left-hand operation refer to the section of these directions titled "*CONVERTING THE CASSETTE CHANGER TO LEFT HAND OPERATION*" for the necessary information.

UNPACKING - Unpack the base casting Fig. 1, Illustration 1. Next unpack the housing Fig. 3 which contains the changing and raising mechanism.

The large box containing the vertical or upright structure shall be placed on the floor so that the vertical structure will rest on its back. The top, sides and ends of the shipping box shall then be knocked out. The bottom of the box is so constructed that the vertical structure is blocked up, making it possible to fasten the base casting Fig. 1 and to install the housing Fig. 3.

ASSEMBLY - Fasten the base Fig. 1 to the vertical structure using the four bolts furnished Fig. 5. The zinc-plated holes are placed at the rear.

Remove the two screws Fig. 8 at the top rear of the vertical structure and take out the two threaded studs Fig. 7 from the front side. Remove the four screws Fig. 6 on each side at the top and lift off the top casting Fig. 9. Place the casting aside temporarily. Remove the stop Fig. 10.

The housing Fig. 3 for the motor and raising mechanism can now be installed. To avoid any possibility of marring the surfaces of the upright structure, when installing the housing, it is recommended that a cloth be placed over each column from the top to a point about midway down. This will prevent the housing from coming in contact with the front side of the columns when positioning the housing. As soon as the rollers and gears are engaged, these cloths can be removed. Using two men, one at each side, place the housing into the upright structure inserting it from the top end. Carefully guide it into place so that the rollers engage their respective tracks properly. Turn the crank, Fig. 11 so that the teeth on the pinion gears will mesh with the teeth on the gear racks.

Run the housing into the structure far enough to permit reinstallation of the stop Fig. 10. Place the top casting in position and fasten it securely to the uprights by means of the screws Fig. 6 on each side. Insert the two threaded studs Fig. 7 in the ears of the top casting, and insert the screws Fig. 8 through the rear panel tightening them down firmly.

The entire assembly can now be stood upright and moved into the position in which it is to be used.

WALL MOUNTING - The base casting for wall mounted installations is fastened to the vertical structure in exactly the same manner as described for floor type installations.

Provision is made for anchoring the unit to the wall by means of the ears

Fig. 12. Illustration 1 on the top casting. First remove the two screws Fig. 8 and the two studs Fig. 7. Bolts or screws can be used for anchoring to the wall depending upon the wall construction.

CONVERTING THE CASSETTE CHANGER TO LEFT-HAND OPERATION - Remove the bottom cover Fig. 17, Illustration #1 by taking out the eight binding head screws and washers which fasten it in place. This gives access to the raising mechanism.

Referring to Illustration #2 loosen the set screw and drive out the pin Fig. 18 in the gear Fig. 19 on the end of the crank shaft. Pull out the shaft and crank. Loosen the two set screws Fig. 20, in the sleeve Fig. 21. Drive out the pin Fig. 2 in the gear Fig. 23 and remove the shaft Fig. 24.

Duplicate holes for the assembly just removed are provided on the left side of the housing. Pry off the cap Fig. 25 on the left of the housing and reinstall on the right. Reassemble the mechanism on the left side in exactly the same manner as it was found in the right. Be sure all pins have been installed and all set screws firmly tightened.

Remove the scale Fig. 29 and the indicator Fig. 28, Illustration #1 from the right-hand column and install them in the same manner on the left column in the holes provided.

ADJUSTMENTS, LEVELING - When correctly leveled, the cassette changer can be leveled by means of a spirit level and the floor pads Fig. 13, at the front and Fig. 14 at the rear of the base casting. Make certain that the cassette changer is exactly in line with the center of the x-ray table.

CASSETTE CHANNELS - The cassette changer is shipped from the factory arranged for use with Rayspeed Universal Cassettes. However, provision is made whereby it can be adapted to different types of cassettes as follows:

Remove the frame on the front of the housing Fig. 3, Illustration #1, by taking out the eight fillister head machine screws which fasten it in place. The bottom cassette channels are held in place by means of four machine screws. Three sets of holes are provided in the housing for fastening the channels. Referring to the table below, fasten the proper channel in the correct set of holes for the type of cassette to be used.

CASSETTE TYPE	HOLES	CHANNELS
Univ-Rayspeed	Top (as shipped from factory)	As shipped from factory
Competitive Make	" "	" " " "
Rayspeed (Bake-lite)	Middle	Use the extra set furnished.
G.E. Al.	Bottom	Special channels must be ordered from the factory

When the channels have been correctly installed, replace the front frame of the housing and fasten in place.

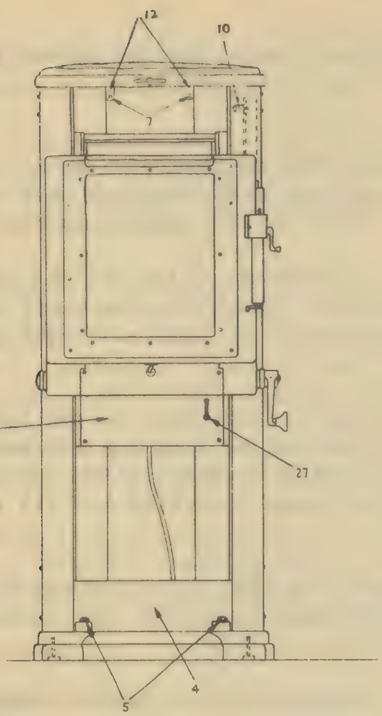


Illustration 1 (Front)

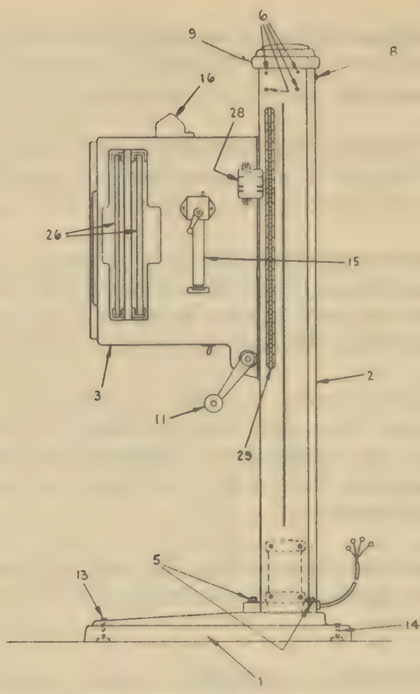


Illustration 1 (Side)

HEIGHT INDICATOR SCALE - The height scale on the cassette changer shall be set up to correspond with the height scale on the tube stand. With the x-ray tube stand carriage turned to face the cassette changer, and with the arrow marked "Table Top" of its index scale opposite "25" on the tube column scale, measure the distance from the floor to the focal spot of the x-ray tube. Then raise or lower the cassette changer so that the distance from the center of the cassette changer panel to the floor will be the same as the distance just measured at the tube stand. Keep the cassette changer in this position and move the height scale so that "25" will be directly opposite the indicator.

The height scale on the cassette changer is mounted on a small channel. To raise or lower the scale, simply force it up or down by pushing the scale from the top or bottom. If the scale binds it can be pried off by inserting a screw driver beneath the bottom edge and working upwards.

BRAKE ADJUSTMENT - If the cassette is not parallel with the front panel of the changer, adjustment should be made on the brake screw Fig. 27, Illustration #1. If the brake is too tight, the brake screw should be turned to the left slightly. If the brake is too free, the screw should be turned to the right. The brake will have to be adjusted slightly when the size and type of cassettes are changed.

IMMOBILIZATION DEVICE - If the Immobilization Device Fig. 15, Illustration #1, is a part of the installation it shall be fastened in place as shown, using the four machine screws furnished. Mounting holes are provided in the housing Fig. 3. Since the cassette changer leaves the factory arranged for right-hand operation, these holes will remain open on the right side of the housing. An ornamental casting will be found mounted in place on the left side of the housing which can be removed and installed on the right, thereby affording the necessary mounting holes for the Immobilization device on the left side if desired.

PAPER DISPENSER - If the paper dispenser Fig. 16, is a part of the installation it shall be fastened at the top of the housing as shown in Illustration #1. The necessary mounting holes are provided in the housing and mounting screws are furnished with the dispenser.

ELECTRICAL SERVICE - Because the cassette changer is usually installed at the foot or head end of the x-ray table and at a considerable distance from the control stand, it is recommended that the wiring between the control stand and the changer be installed in concealed or exposed conduit. Refer to Illustration #9 for the necessary conduit and wiring information.

If it is desired to install the unit without using conduit, it may be connected to the control stand by means of the 4-conductor rubber-covered cable furnished.

ELECTRICAL CONNECTIONS - Having completed assembly of the unit, check the attached Illustrations 3 to 8 and choose the diagram for the control stand on the installation. Make all connections as shown on the wiring diagram.

Note that when installing the cassette changer in conjunction with a motor-driven vertical stereo-shifter, Illustration 6, it will not be necessary to use the relay in the control stand that was required with the balanced cassette changer.

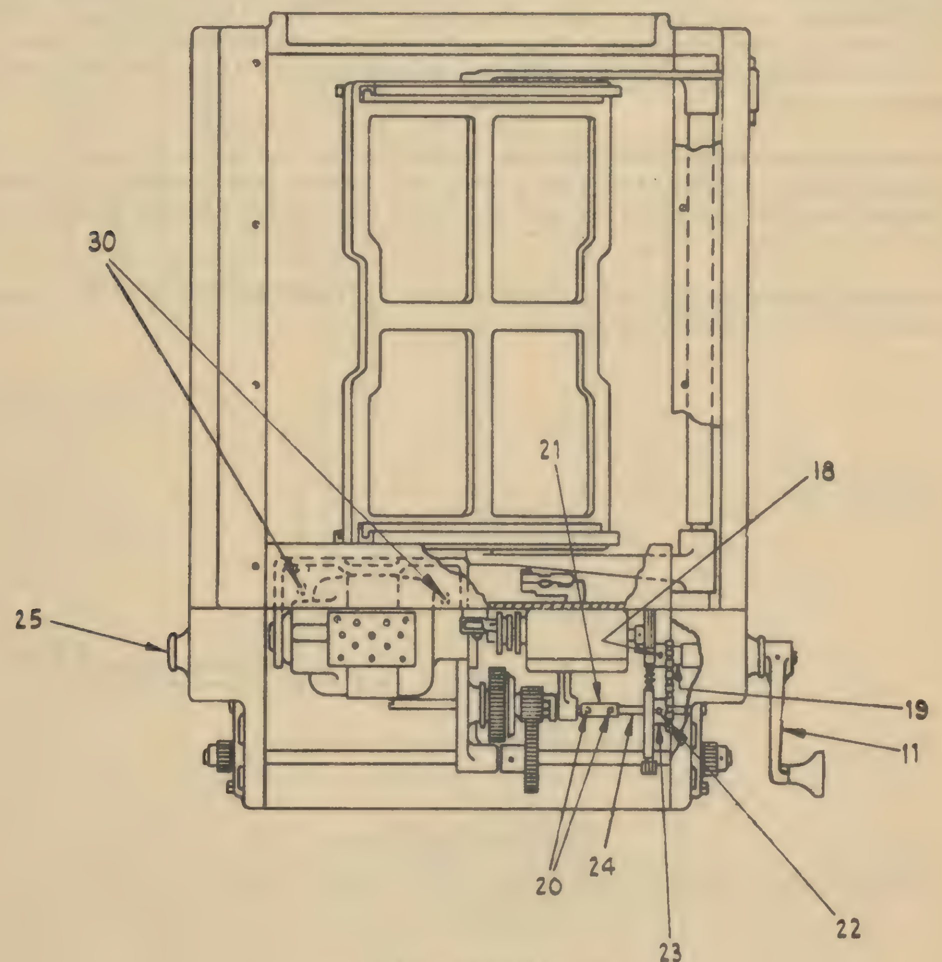


Illustration 2

TESTING UNIT - Place two 14" x 17" cassettes in the cassette changer channels, Fig. 26, Illustration 1, with the front of the cassettes outward. Set the tube stand stereo-shifter as indicated in its directions for operation.

Place the control stand line switch in the "on" position. Press the "Stereo" hand switch button; the cassettes should rotate so that the rear cassette moves to the front of the changer and the tube carriage should move the distance for which it was set.

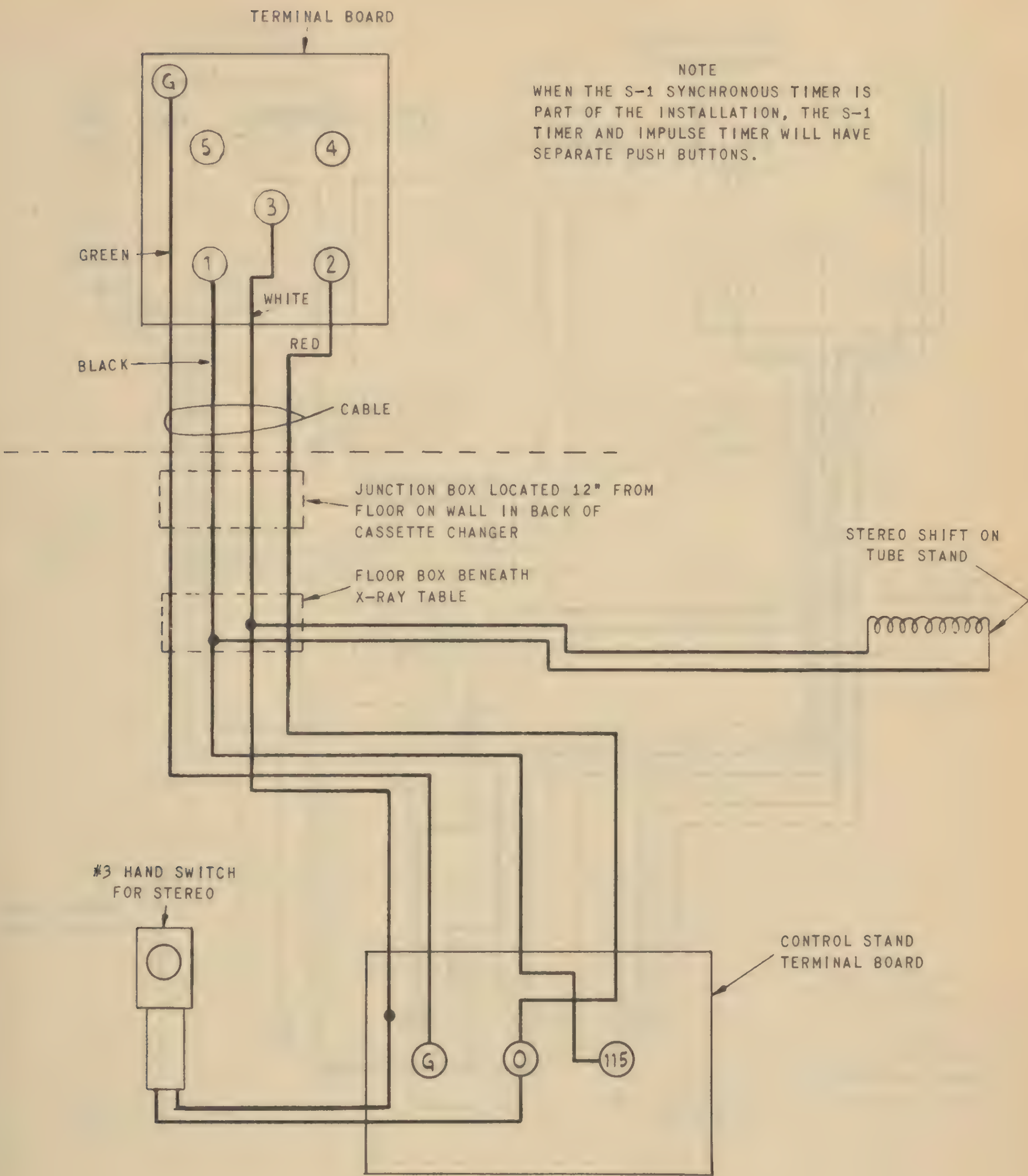
Repeat the above test 10 times and observe if the cassette always ends its travel so that the front of the cassette is parallel with the front of the changer. If the cassette is not parallel, adjustment should be made on the brake screw Fig. 27, Illustration 1 as indicated in the section titled "BRAKE ADJUSTMENT".

When using the magnetic release type of tube stand stereo-shifter, it is not necessary to hold the stereo button down during the entire excursion of the cassette mechanism. However, on the motor type stereo-shifter, it is necessary to press the button until the x-ray tube has completed its travel on the tube stand.

MAINTENANCE - If the cassette changer is properly installed, connected and adjusted, it should not require any future attention other than perhaps oiling the two motor bearings and slight brake adjustment Fig. 27, Illustration 1, which can readily be done by the customer. The serviceman should explain this brake adjustment to the customer so he will be able to do the work in the event that adjustment should be necessary.

It may be necessary to adjust the brake in the winter and summer. When the ambient temperature is high, the gear grease may become less viscous. In this case, the mechanism may become too free and the unit may recycle until the control line switch is turned off.

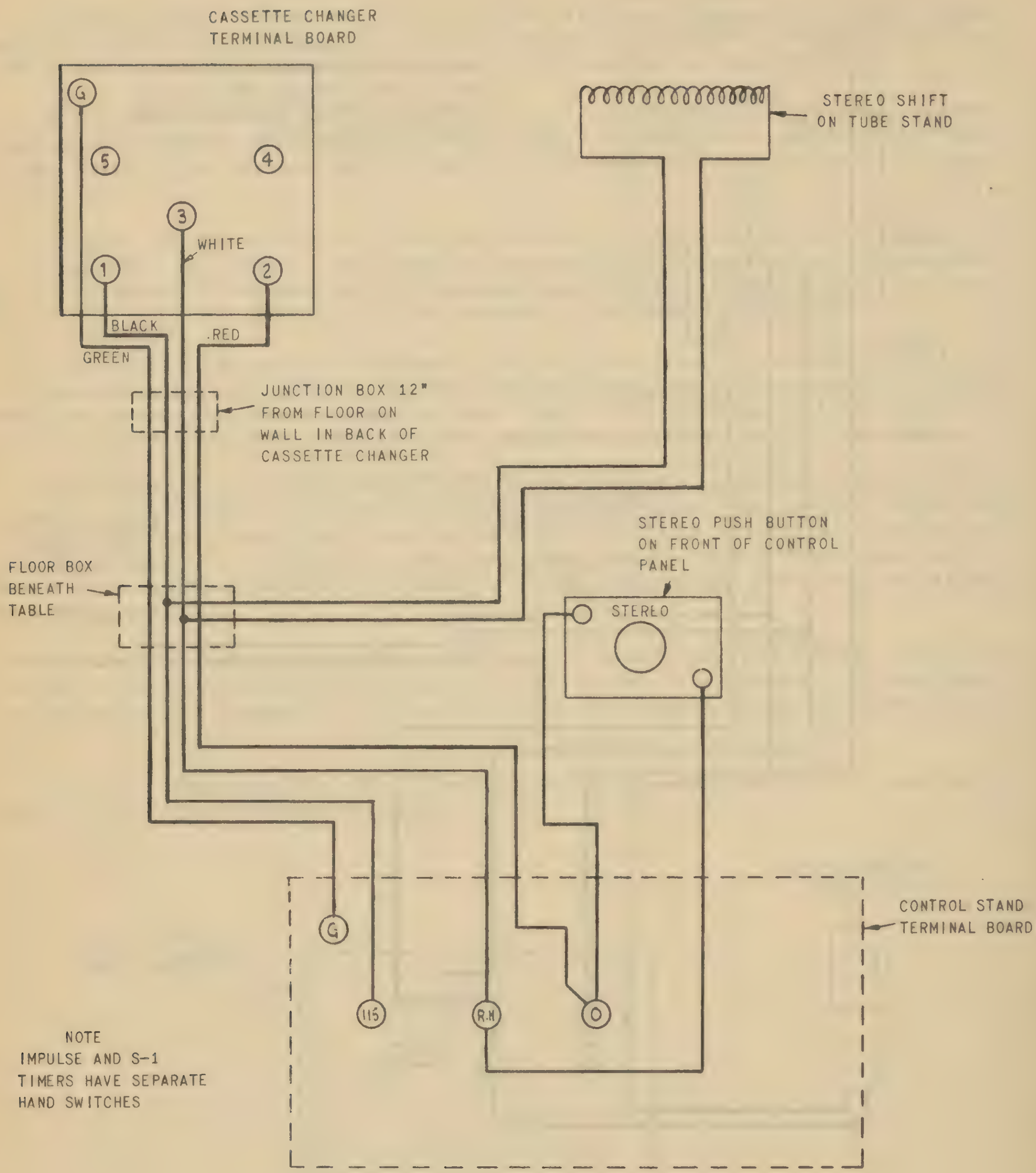
The motor bearings Fig. 30, Illustration 2, shall be oiled with a good grade medium motor oil once every six months.



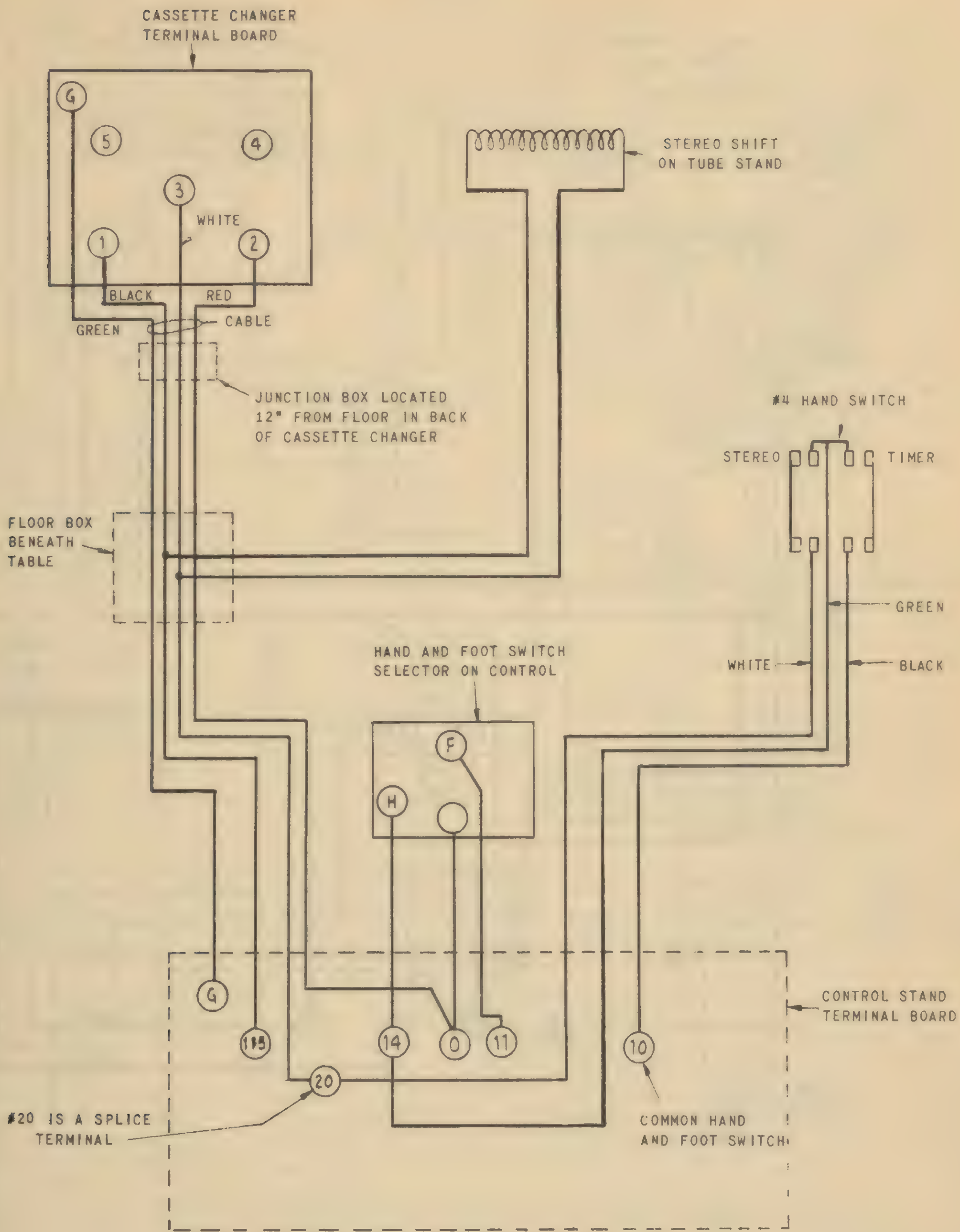
CASSETTE CHANGER

STANDARD INSTALLATION WITH SINGLE PUSH BUTTON AND A S-1 SYNCHRONOUS TIMER

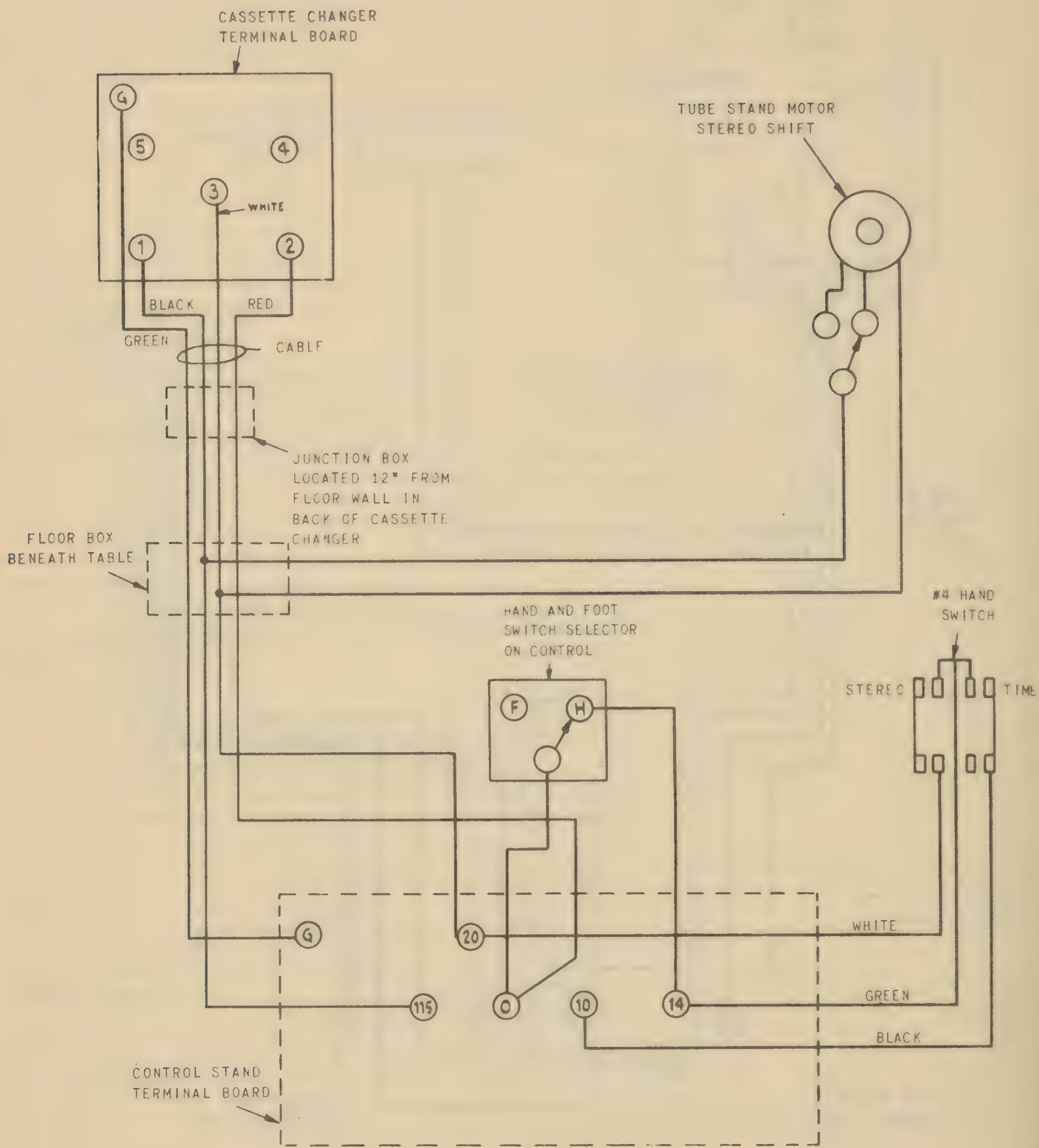
Illustration 3



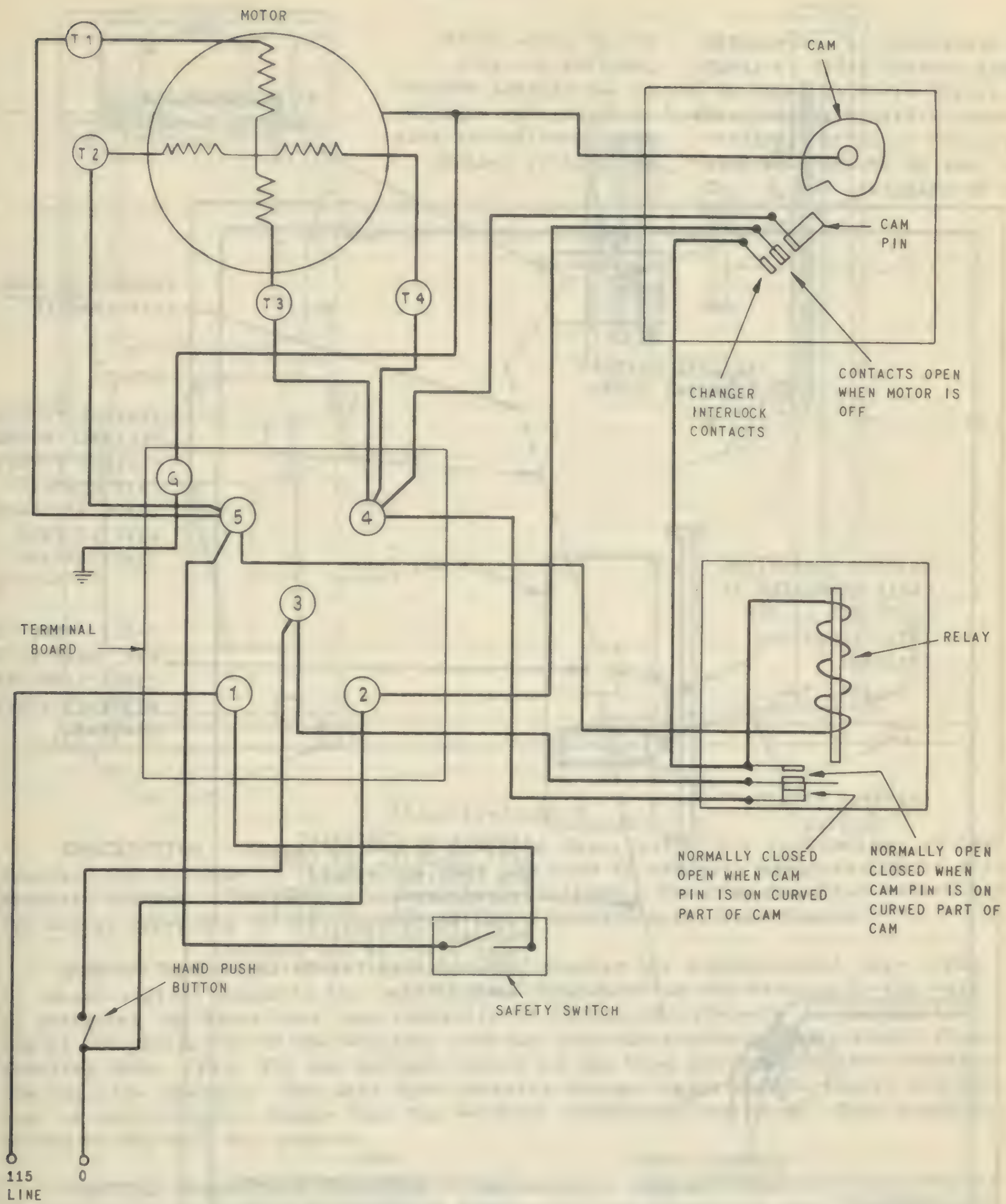
CASSETTE CHANGER
KX-8 TYPE 4 CONTROL STAND WITH S-1 SYNCHRONOUS TIMER,
TYPE I-1 IMPULSE TIMER AND STEREO SHIFT PUSH BUTTON
MOUNTED ON FRONT PANEL
Illustration 4



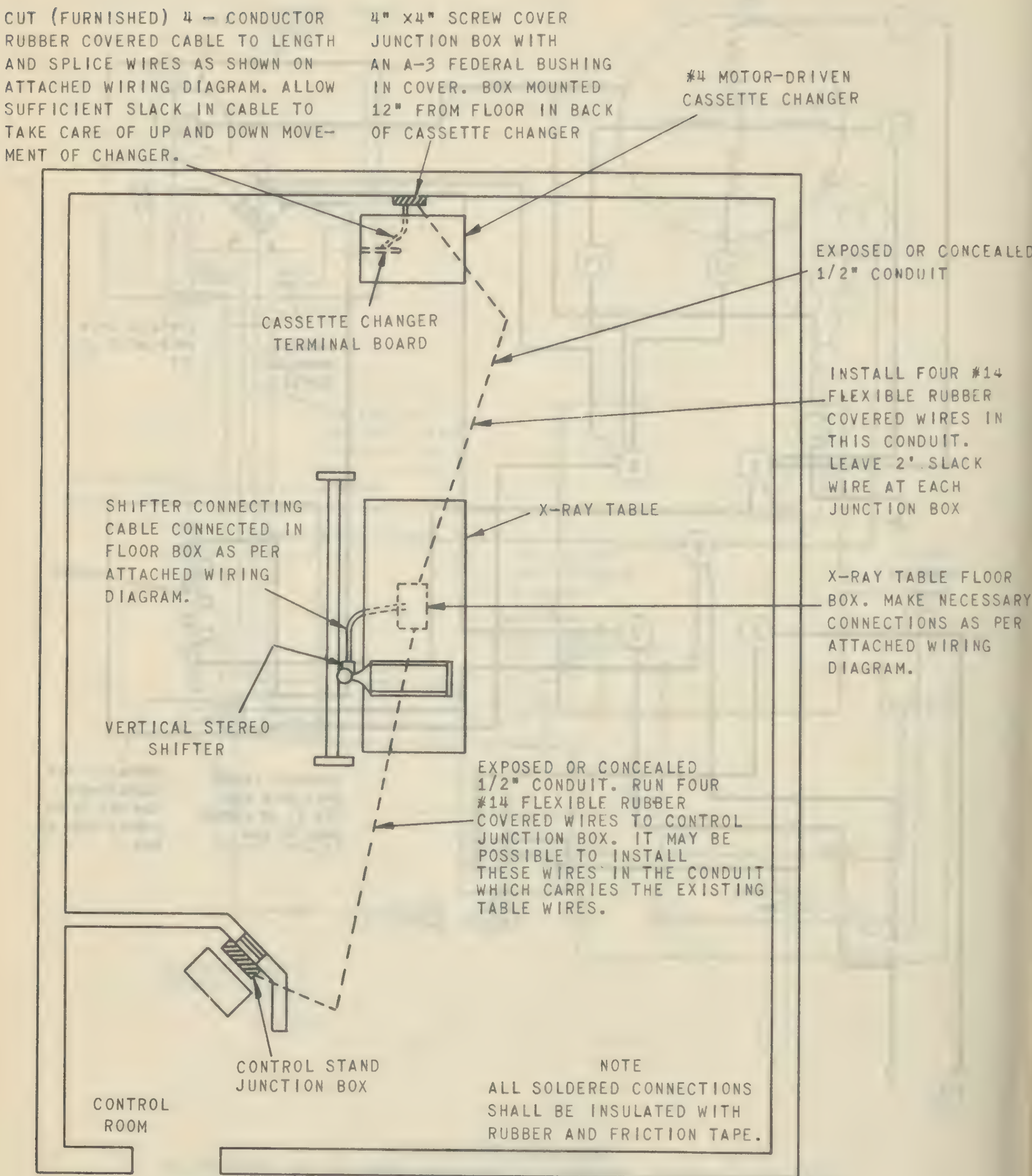
CASSETTE CHANGER
CONTROL STAND EQUIPPED WITH TYPE S-2
OR S-3 TIMER AND A TYPE I-2 IMPULSE TIMER
Illustration 5



CASSETTE CHANGER
R-39 UNIT WITH TYPE S-2 OR S-3 TIMER, MOTOR OPERATED
STEREO SHIFT AND A TWO BUTTON HAND SWITCH
Illustration 6



CASSETTE CHANGER
SCHEMATIC WIRING DIAGRAM OF CASSETTE CHANGER MECHANISM
Illustration 7



MOTOR-DRIVEN CASSETTE CHANGER
TYPICAL CONDUIT AND WIRING LAYOUT FOR INSTALLATION
Illustration 8

OPERATION

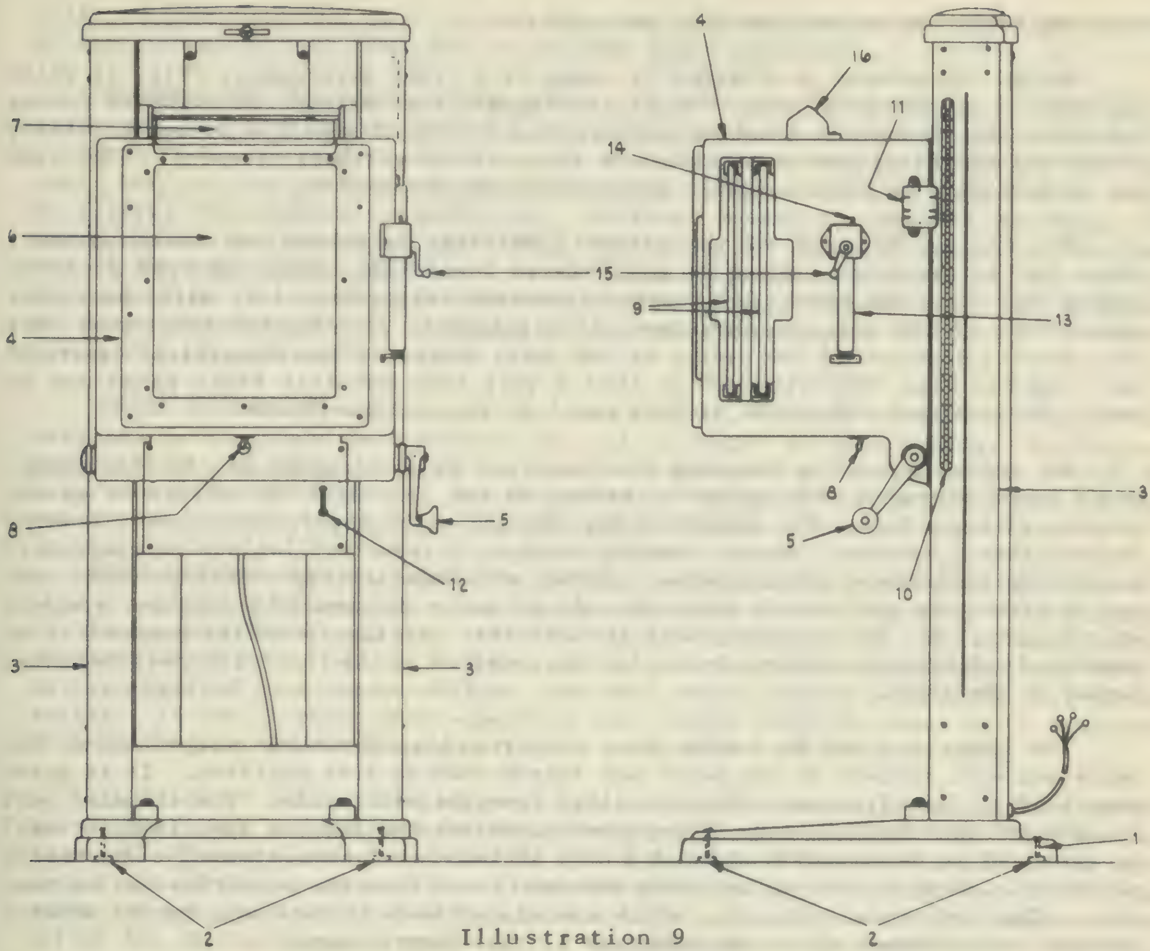


Illustration 9

DESCRIPTION - There follows a detailed description and explanation of the function and purpose of all devices that are used in ordinary manipulation of the cassette changer. The number in parenthesis following the item described refers to the number appearing on the diagram and thus identifying the item thereon.

SUPPORT BASE - The floor type cassette changer has a substantial base, (Fig. 1), which rigidly supports the unit without dependence on any bracing to the wall. In designing the floor base, the necessity of minimum interference to the positioning of the patient or of the hospital cart has been taken into consideration. Floor leveling pads, (Fig. 2), one on each corner of the base are provided for leveling the cassette changer. The wall type cassette changer rests on the floor, but its base is only slightly larger than the vertical supporting structure. This model is bolted to the wall for support.

VERTICAL SUPPORTING STRUCTURE - The vertical support structure consists of two fabricated steel upright columns, back panel, and ornamental top. Incorporated in the upright columns are racks, (Fig. 3), and rail tracks for vertical movement of the cassette carriage. Bolted to the base unit, the vertical support forms an extremely rigid vibrationless structure.

CASSETTE CARRIAGE - The cassette carriage, (Fig. 4), is vertically adjustable from 36 to 59 inches measured to the center of a 14 by 17 Rayspeed cassette or

from 46½ to 69 inches measured from the chin rest.

Height adjustment is obtained by means of a crank arrangement (Fig. 5) which includes an automatic clutch. The clutch engages the instant the crank is turned but locks the moment the cranking ceases, thus making it possible to automatically retain any height of position within the range of the vertical movement. The crank may be installed on either side at the convenience of the user.

The front, (Fig. 6), of the cassette carriage is curved and the chin rest, (Fig. 7), is recessed, making it possible to locate the apices of even a short-necked person on the film. All obstructions which might interfere with the proper positioning of the arms and shoulders are eliminated. Curving the front panel not only permits location of the center of the chest nearer to the geometrical center of the film but also adds strength so that a very thin bakelite front panel may be used. The inherent filtration of this panel is thus extremely low.

The motive power for changing the cassettes is provided by an electric motor. Being motor operated, the cassette changer is not sensitive to variations of the weights of cassettes. The cassettes are changed without jar, noise, or vibration in less than 2 seconds. Should jamming occur as a result of failure to completely insert the cassette or for any other reason, an automatic slip clutch prevents damage to either the unit or the cassette. As a further measure of protection a safety switch, (Fig. 8), is provided under the cassette carriage permitting power to be completely disconnected when desired. This switch is in the "off" position when turned to the right.

The cassettes can be loaded from either side. Automatic stops orient the cassettes with respect to the panel and retain them in that position. It is quite practical to load from one side and unload from the other side. The standard unit is arranged for the G-E 14 by 17 Rayspeed cassettes but when so specified, it will be arranged to accommodate the G-E 14 by 17 Universal cassettes or competitive cassettes. With the aid of suitable adapters, smaller type cassettes can be used also. The cassettes, (Fig. 9), which are placed back to back are turned about a vertical axis between the x-ray exposures by the electric motor.

VERTICAL SCALE - Graduated in both inches and centimeters the vertical height indication scale, (Fig. 10), may be on either side as desired. The scale is so arranged that it can be readily adjusted to correspond with the height scale on the x-ray tube stand. Mounted on the cassette carriage and adjacent to the height scale is an index scale, (Fig. 11). The index scale has three lines, each of which is identified by the type and size of the cassette.

SAFETY SWITCH - The safety switch, (Fig. 8), is located on the under side of the cassette carriage and serves as a further measure of protection permitting the power to be disconnected when necessary or desired. This switch is in the "off" position when turned to the right.

BRAKE ADJUSTMENT SCREW - The brake adjustment screw, (Fig. 12), is located at the right on the lower side of the cassette carriage. Its function is to control the brake so that on shifting the cassettes may stop in central position, that is parallel to the front panel of the cassette carriage. Its adjustment requires that a screwdriver be inserted in the opening.

DESCRIPTION OF OPTIONAL AND RELATED ITEMS - In considering the design of the new motor-driven cassette changer, it was felt that there was a definite need for a compression and immobilizing band and a paper dispenser, but it also appeared

quite evident that this need was not universal. These devices are therefore listed as accessories so that those who desire them might have them.

COMPRESSION AND IMMOBILIZING DEVICE - This device, (Fig. 13), is crank operated, and positive locking and is equipped with an instant release. It can be attached to be operated from either side of the cassette changer as specified. The small lever on top of the compression device is a ratchet release lever, (Fig. 14). To release the compression band, turn the lever toward the back of the unit. To engage the ratchet mechanism, turn the lever toward the front of the unit. The free end of the compression band has a metal strip which permits anchoring the band in the retention slot on the side of the cassette carriage opposite to that on which the immobilizing device is assembled and applying compression by means of the compression crank, (Fig. 15).

PAPER DISPENSER - The paper dispenser, (Fig. 16), is mounted on top of the cassette carriage and accommodates one roll of paper 13 inches wide. Sufficient paper may be withdrawn to cover the chin rest and neck of the patient or enough to cover the whole front panel. The dispenser is equipped with a tear plate. A new paper roll can be quickly and easily installed without the aid of any tools.

HAND SWITCH - Operation of the shifting mechanism is controlled by means of a hand switch. Although the motor must run the entire shifting cycle, the function of the hand switch is only to start the cycle. Once started, the mechanism will continue through the entire shifting cycle. If the tube stand is equipped with a spring-operated tube stereo-shifter, the hand switch should be pressed only momentarily. If the electric motor-operated tube stereo shift is used, it is necessary to hold the hand switch pressed until the x-ray tube shift is completed.

A choice of two hand switches is offered. One is a single button hand switch and another is a two-button hand switch with one button marked "timer" and another "stereo". The hand switch is provided with a cord which can be attached at the control stand of the x-ray unit or at the cassette changer. Certain models of x-ray units are equipped with two-button hand switches, the purchase of a separate hand switch for controlling the operation of the cassette changer will not be necessary in such cases.

OPERATION - Operation of various devices and controls used in the cassette changer is extremely simple, and becomes obvious on reading their description. Step-by-step procedure, is, however, presented so that it may be carried out routinely in the preferred sequence.

Load the cassette carriage with a pair of cassettes for the size and type of which the lower tracks in the cassette carriage have been adjusted. Be sure that the cassettes are placed back to back and are pushed in all the way.

Draw sufficient paper from the paper dispenser to cover the chin rest or whole front panel as desired.

Position the patient in front of the cassette changer with the chin resting on the chin rest. The patient should be positioned according to standard practice.

Raise the cassette changer carriage by means of the crank until the patient's chest is properly centered to the front panel of the cassette carriage and the patient's head is tilted slightly upward.

If immobilization is desired, turn the ratchet release lever on the compression device to the back of the unit and draw the band out sufficiently to pass over the

back of the patient. Anchor the metal strip on the free ends of the compression band in the retention slot on the side of the unit opposite to that on which the compression device is mounted. Turn the ratchet release lever toward the front of the unit and turn the compression crank until the desired degree of compression is obtained.

Read the height of the cassette carriage on the vertical scale opposite the appropriate line on the index scale. The proper line on the index scale is determined by the type of cassette chosen for use in the cassette changer.

SECTION XXVIII

CASSETTE CHANGER - W - HORIZONTAL

CASSETTE CHANGER (W) HORIZONTAL

INSTRUCTIONS FOR OPERATION AND INSTALLATION OF WESTINGHOUSE HORIZONTAL CASSETTE CHANGER

UNPACKING - This cassette changer is shipped in one large-size crate. The uprights and the horizontal carriage assembly are packed in the same crate. When opening the crate, the horizontal carriage will be found up-ended and placed between the two uprights. The horizontal carriage should be removed from the crate, leaving the wrapping paper on, and laid aside, until the uprights have been placed in position. The upright assembly is shipped completely assembled and it is necessary only to move it into place.

SETTING UP - On the four corners of the large U-shaped base casting will be found holes whereby leveling may be accomplished. On the rear member of the casting is found a 90° water level glass. This is for the purpose of obtaining proper leveling, regardless of floor contours. Do not attempt to move the leveling screws with the weight of the uprights upon them. If, for example, it becomes necessary to make any adjustment of the four corners, jam a screwdriver or other wedge-shaped device between the base and the floor to take the weight off the leveling pad, make the adjustment, and remove the wedge. Attempting to move these leveling screws with the full weight of the casting upon them may result in a broken screwdriver. Inasmuch as this unit operates on the principle of gravity and has no electrical devices of any type except its trip mechanism, the leveling is of extreme importance.

After the uprights have been leveled, install the horizontal carriage. This can be accomplished by means of the eight hexagon machine bolts supplied. Fasten the carriage through the eight holes in the upright assembly. After these have been securely tightened it will be possible to remove the two long shipping bolts which are located approximately six inches from the bottom of the large chrome plated columns of the upright. These bolts are intended solely for the purpose of securing the counterweights during shipment of the device. It is suggested that these bolts be kept handy in the event of reshipment of the unit at some future date.

OPERATION - The trip mechanism can be operated either mechanically or electrically. Inasmuch as the unit will only operate in one direction, an indicator located in the upper right-hand side of the horizontal carriage is utilized to indicate the No.1 and No. 2 positions of the moving frame which holds the cassettes. Make certain that before a stereoscopic exposure is attempted No. 1 shows in the small indicator block. To set the mechanism from the No. 2 to the No. 1 position (preparatory to taking a second set of films) it is necessary to move the handle, on the right-hand edge of the horizontal carriage, down. The device cannot be cocked electrically.

By opening the center door and moving the assembly, various adjustments will be seen for accommodating various sized cassettes. The mechanism for holding the cassettes in place permits the cassettes to be snapped into place and it is held securely in place by a spring trip. To remove the cassette it is necessary only to lift this trip mechanism and the cassette will be pushed out by means of a heavy spring behind the cassette.

The compression device can be mounted for either right-hand or left-hand operation. Make certain that the holding end of the compression device is installed in such a manner that the compression tension band will be against the hook of the bar holding the compression band end.

The magnetic trip mechanism is the means whereby the solenoid coil may be connected in parallel with the trip mechanism of the stereoscopic shift on the tube stand. This will eliminate the need of a separate push-button control for either device. By making a parallel connection between the cassette changer and tube stand coils, one push button can operate both devices. The cassette changer trip mechanism

has a small mercury switch inserted in one side of the coil. This unit will complete the solenoid circuit only when the mechanism is in the No. 1 position. It is purely a safety device to prevent the voltage from being on a trip coil for an excessive length of time.

ADJUSTMENTS - On a right-hand column facing the cassette changer will be found a long vertical scale. This scale can be adjusted by the multitude of holes that are drilled in the scale and can be made to line up with the scale on the vertical column of the tube stand. This adjustment should be made by the serviceman so the technician operating the unit can line up the white line indicator on the horizontal carriage of the cassette changer to coincide with the scale on the tube stand. This avoids the necessity of making a measurement each time a stereoscopic examination is made.

In the back of the cassette changer will be found a plunger-like assembly which is the means of cushioning the shock of the moving member when changing from No. 1 to No. 2 position. This assembly utilizes a spring and air chamber for softening the shock of the moving carriage. In the event of excessive vibration (when the change is made) loosen one of the two screws that hold this assembly and move this assembly in or out as required. In the event the cassette device is tripped and it does not catch hold satisfactorily, it will probably mean that the plunger assembly is advanced too far.

The assembly is equipped with a special wall bracket which, if required, can be used to fasten the tops of the two columns to the wall. The V-shaped bracket will have two holes in each end at its widest point. These will fit into the castings of the tops of the cassette changer uprights.

The vertical carriage assemblies operating over the chrome-plated columns are properly adjusted. If the rollers are found too tight or too loose, it will be necessary to move one roller. In each set of roller bearing assemblies, there will be found one excentric stud which permits the bearing to be moved closer to, or further away from, the vertical column. The small lead disks on the back of the segments are intended primarily to compensate for the various weights of different manufacturers' cassettes.

MAINTENANCE - The maintenance of the unit requires cleanliness. The track upon which the segments operate should be clean and free of foreign material and dust. The bearings operating on the vertical uprights should be clean. If the bearings should become filled with dust or foreign material, always make a thorough job of cleaning. This can be accomplished by removing the bearing and washing it thoroughly in kerosene or gasoline and repacking with a good grade of light lubricating grease or vaseline.

SECTION XXIX

STANDARD CASSETTE CHANGER

INSTRUCTIONS FOR ASSEMBLING AND OPERATING
STANDARD MOTOR DRIVEN
HORIZONTAL CASSETTE CHANGER MODEL HCC

This equipment is shipped in three cases, one of which contains the entire frame, the other contains the mechanism, and the third the "feet".

Unpack the crate and mount the "feet" on the columns. Tighten them firmly and adjust the leveling screws in the "feet", until the columns are perfectly vertical. Check the columns on all sides with a spirit level.

Set the mechanism on a box between the two legs and attach the mechanism to the four roller brackets. The top roller brackets are each attached by means of two cap screws. The bottom roller brackets are each attached by means of two cap screws and one machine screw. You will have to open the door of the case to see the hole through which the machine screw passes, in order to attach the case to the front ends of the bottom brackets.

Lift the mechanism to the top of its travel. Remove the two nuts from the studs on the ends of the counterweight chains, being careful that the chain does not get away and fall back into the tube column. Thread these chains through the top bar of the mechanism, then replace one nut on each stud. Adjust these nuts until the mechanism frame is perfectly horizontal when checked with a spirit level. Replace the other nuts on the studs and tighten them firmly against the first nuts without changing the above adjustment.

Insert the long lock rod and handle from the right hand end; it passes through one guide hole and two clamp castings, one on each leg. If either of these castings does not hold firmly when the lock handle is tightened, it can be adjusted by means of the two lock nuts which are on the stud which passes through the slot that is in one end of each clamp casting.

The counterweights are held in place in the columns by means of screws which will be found near the bottom of each column. Do not remove these screws until after the counterweights have been attached.

The Standard Motor Driven Horizontal Cassette Changer has an operating mechanism which consists of a motor, an electric brake for the motor, a limit switch that is operated by the motor and a relay which is controlled by this limit switch and by the push buttons that are on the cassette changer and in the control panel. Its operation is as follows:

Pressing either of these two push buttons causes the relay coil to be energized. When pressure on the push button is released, the relay coil operates a set of contacts which starts the motor and releases the electric brake in the cassette changer and energizes the stereoshift magnetic release on the tube stand.

The motor is attached through reducing gears and a pair of arms to the cassette carriage.

The cassette carriage moves slowly at first. Its speed increases steadily until it has reached the middle of its travel. From that point onward, its speed decreases. At the end of its travel the motor operates the limit switch which causes the relay to operate again and shut off the current from the motor and the electric brake.

The speed of travel of the cassette carriage is not adjustable. It has been set at the factory to make the shift in two seconds because it has been found from

experience that at least two seconds are required for the radiographic tube stand to shift and to cease vibrating at the end of its stereoscopic shift.

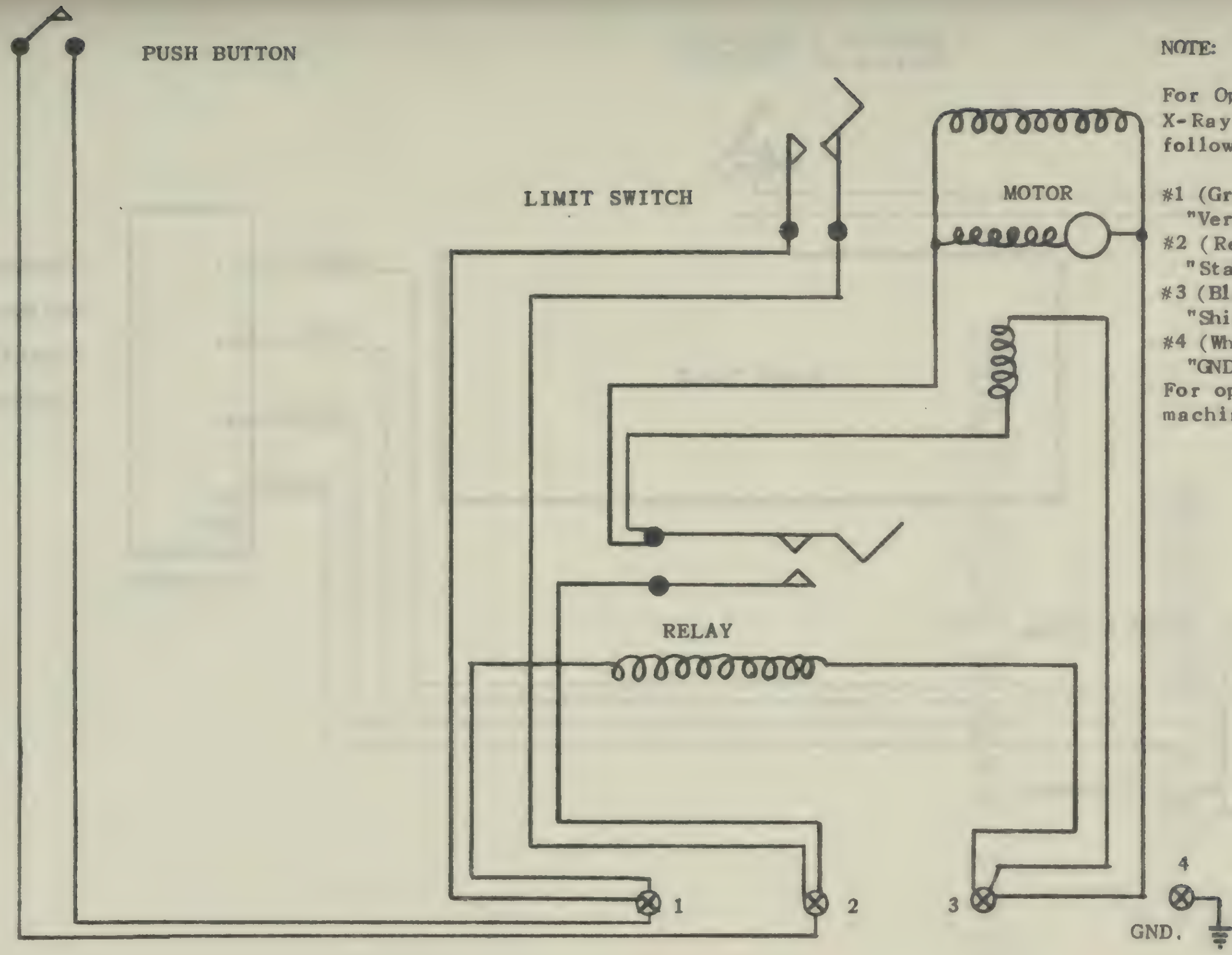
SERVICE - The bearings of the motor reducing gears should be oiled at least once every six months with a good medium grade of machine oil.

The operating lever and the ratchet wheel shaft of the relay should be similarly lubricated. If the apparatus should ever fail to operate satisfactorily, the trouble will probably be caused by lack of lubrication of these moving parts.

Care should be taken not to cause oil to run down on to the small bakelite shoe which is just below the motor and which serves to prevent excessive coasting of the motor after the current has been turned off.

If the motor drive equipment should ever become inoperative, it can be disconnected from the cassette carriage by removing the screw from the center of the bearing on the arm which attaches from the motor mechanism to the cassette carriage. The cassette carriage can then be shifted manually.

If the carriage bumps at either end of its travel, loosen the long post to which the long lever is attached on the cassette carriage frame and turn it about one eighth of a turn. This will either correct the bumping or it will cause the mechanism to bump harder. If the mechanism bumps harder, loosen this post and turn it about one eighth to one fourth turn in the opposite direction. This should never be necessary because the carriage is properly adjusted before leaving the factory.

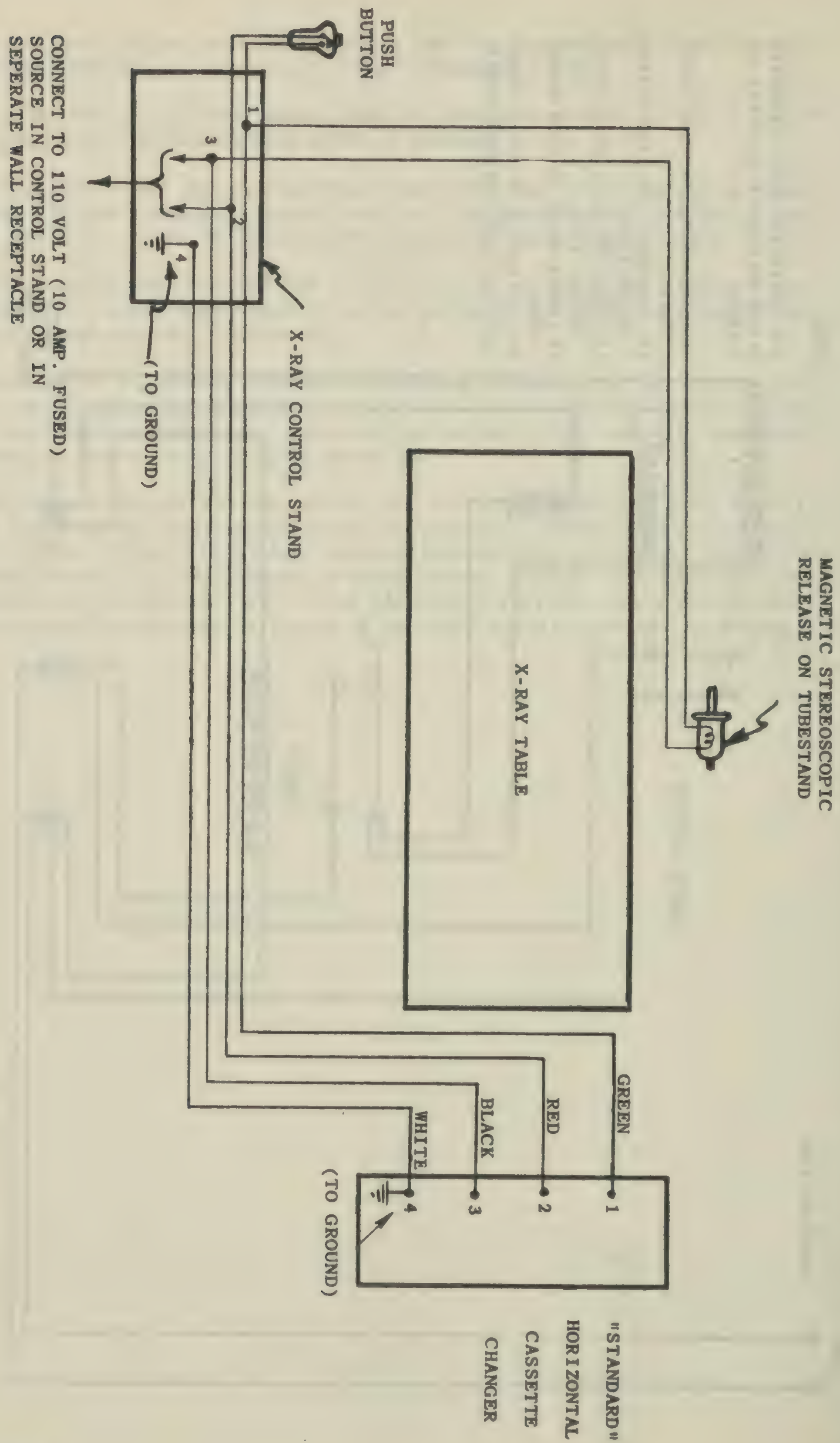


NOTE:

For Operation with Standard X-Ray Machines connect as follows:

#1 (Green Wire) to stud marked "Vert".
#2 (Red Wire) to stud marked "Stab" 110V.
#3 (Black Wire) to stud marked "Shift" 110V.
#4 (White Wire) to stud marked "GND".
For operation with any other machine, see diagram A-972.

WIRING DIAGRAM FOR M.D. HORIZONTAL CASSETTE CHANGER   A-577



WIRING LAYOUT FOR CONNECTING "STANDARD" CASSETTE CHANGER TO ANY MACHINE A-972

SECTION XXX

PORTABLE X-RAY UNITS

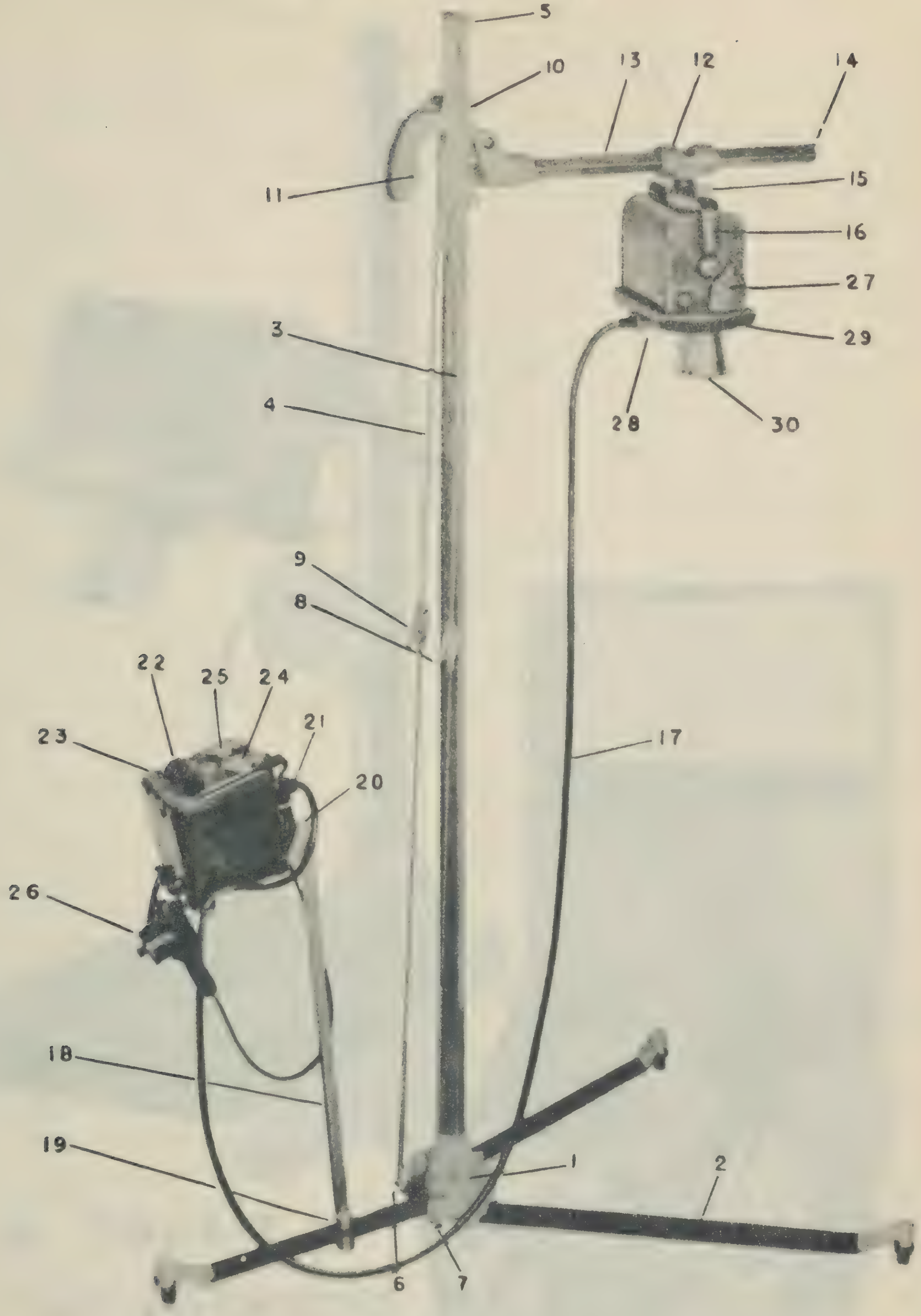


FIGURE A
STYLE "P" COLLAPSIBLE UNIT

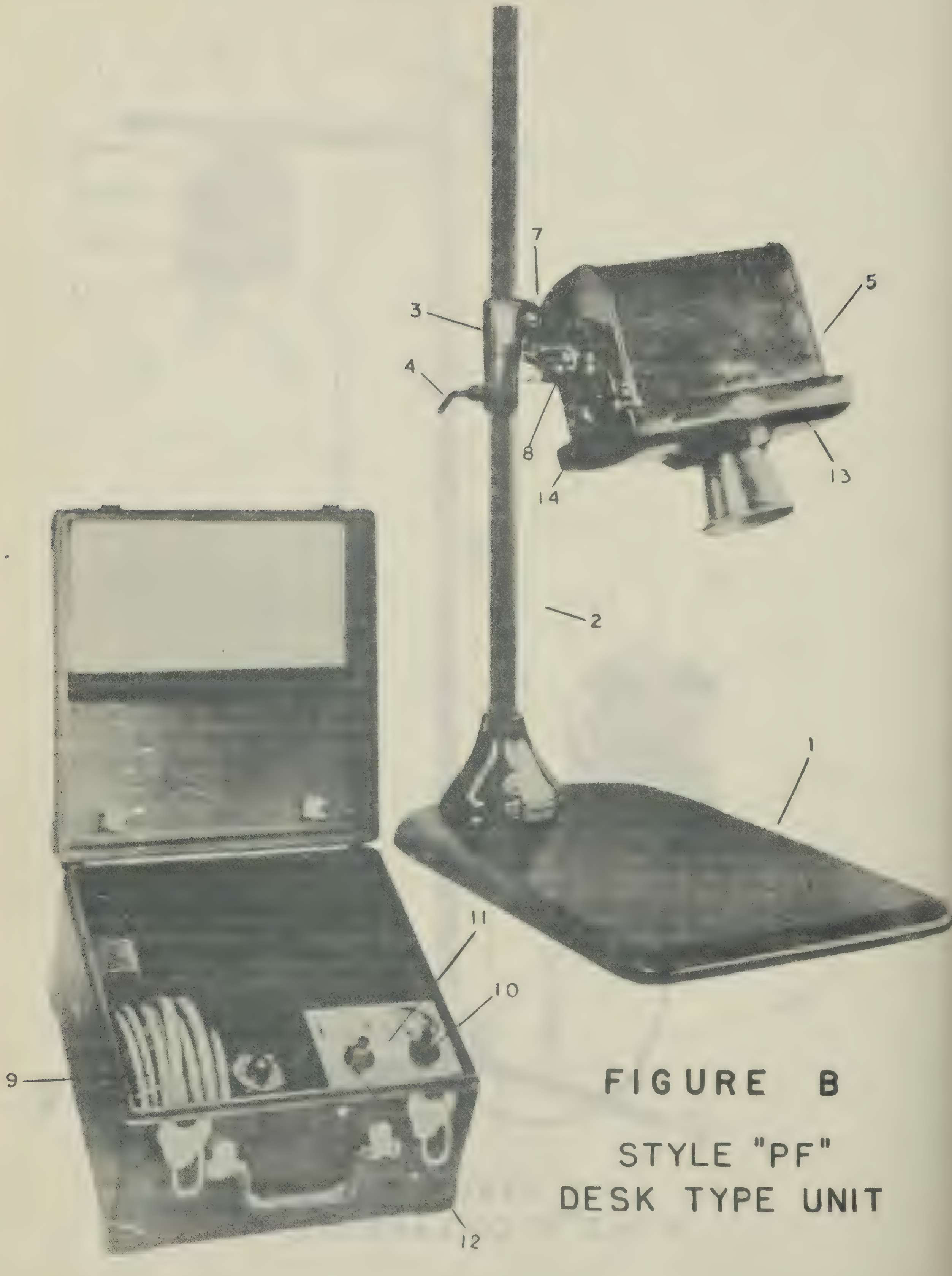


FIGURE B

STYLE "PF"
DESK TYPE UNIT

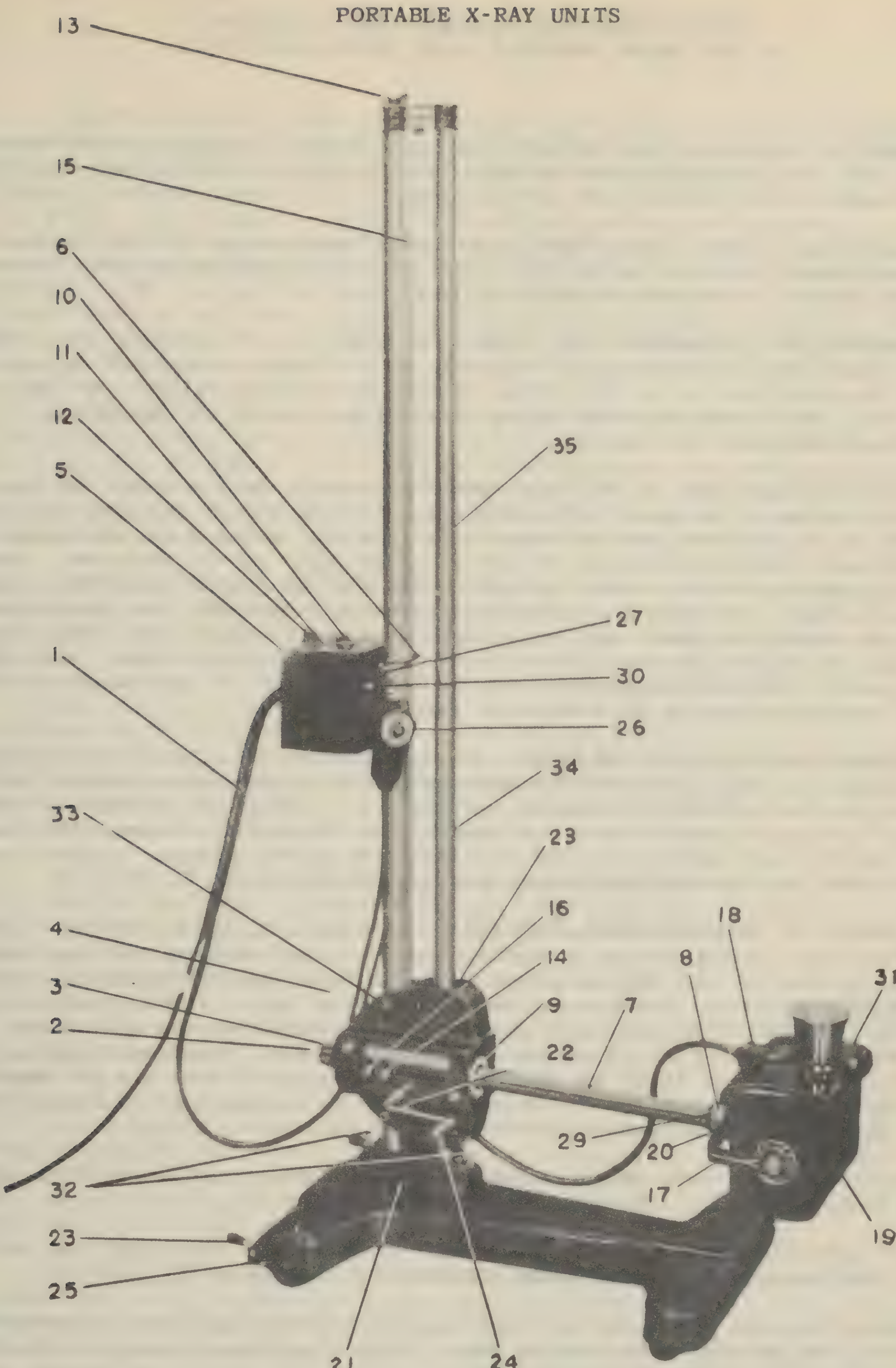


FIGURE C
STYLE "PM" PORTABLE-MOBILE

INSTRUCTIONS FOR ASSEMBLY AND OPERATION OF THE WAITE PORTABLE 15 MA SHOCKPROOF UNITS

UNPACKING - Assuming that the unit has been unpacked, a careful check should be made with the packing slip and the parts of the unit to be absolutely certain that no parts be left in any of the packing cases.

If shortages occur, they should be reported immediately. If the equipment shows any signs of external injury, the crates should be examined and the incident should be reported to the Medical Supply Officer.

ASSEMBLY OF COLLAPSIBLE TUBE STAND - As found in the carrying case, the base 1, Figure "A", together with the legs 2, will be found on top, and the upper part of the stand will be on the bottom. Remove the base and release each leg 2, Figure "A". Swing each leg under and up until it catches in the spring clip attached to the bottom of the base 1.

Remove the upper part of the stand from the carrying case and insert the casting on the bottom of the upper half of the stand into the top of the lower half of the stand in the position shown in Figure "A". You will notice a pin protruding a short distance from the casting at the bottom of the upper half of the stand. This should be placed so it will index or rest in the slot cut in the top of the lower half of the stand. Now release the side stays 3 and 4, Figure "A", from the holding pins 5 and attach the lower ends to the base at 6 and 7, Figure "A". Then lock these rods by pulling the lock levers 8 and 9 into the position shown (with the handles down). The horizontal arm 13 can now be moved over the full height of the upright column by releasing the trigger 11, Figure "A".

ASSEMBLY OF DESK TYPE TUBE STAND - Refer to Figure "B". Insert the upright column 2 into the base 1 such that the numerals on the upright column face the white stripe on the base. Slide the vertical carriage 3 over the upright column such that the white stripe is up and facing the numerals on the upright column. The lock lever 4 is then tightened on the lower left hand side of the carriage. Be sure that the lock lever has been tightened before mounting the tube head.

ASSEMBLY OF PORTABLE-MOBILE TUBE STAND - Set base 25, Figure "C" on floor. Grasp lower mast 34 and carriage assembly by means of mast members (not carriage) and place on base so that wing screws 32 engage in their respective sockets. Note dial position on nose of carriage is toward head end of unit. Tighten wing screws securely. Now insert top mast section 35 in lower section so that gear racks 15 coincide. Tighten wing nut 13 on top of rear mast firmly. Crank carriage up to waist height. Unscrew thumb nut 2, Figure "C" from end of tube arm 7. Remove bumper and retaining cup 3. Slide the arm through the opening in the carriage and restore parts to their original positions on end of the arm.

Rotation of the tube arm 7 is indicated on the dial 9 by means of the two grooved lines running the full length of the arm.

A 4" manually operated stereoscopic shift is provided. When using the shift tighten thumb screw 14. This restricts the motion of the arm to 4".

Fibre shoes 33, Figure "C" are used to guide the carriage on the rear mast. They are all adjustable to take up for wear. These shoes should never be adjusted so they apply any friction to the carriage.

The adjusting screw 22, Figure "C" controls the friction on the lifting mechanism. If the carriage should ever tend to slip, *increase* the friction by turning the screw *in* slightly. Be sure to lock after adjustment.

MOUNTING THE TUBE HEADS - The tube heads supplied with any one of the units described in this manual are all similar and interchangeable. Before mounting the tube head on a stand the taper pin with the knurled head 15, Figure "A", should be removed from the head support or yoke 16. The yoke should then be ready to fit on the stand. It is important that the tapered pin be installed properly. It will be noticed that the tapered hole in the mounting shafts is slightly countersunk on one side. This is the side which the tapered pin must enter before the pin engages the threads in the yoke or head support. It is advisable to tighten this pin well. The knurled head of this taper pin is slotted so that a coin may be inserted and used in place of a screw driver for this operation. It is necessary to use care and not tighten this screw so much that the thread or the taper pin will be injured.

MOUNTING THE HEAD ON COLLAPSIBLE TUBESTAND - Remove the carriage 12 from the arm 13, Figure "A", by sliding over the stop 14. Fit the pivot shaft on the carriage into the hole in the tube head yoke and insert the taper pin as per paragraph 11. In some cases it will be necessary to use the extra shim washers that are tied to the yoke in order to secure the proper fit of this taper pin. A tag is attached to these washers giving instructions on how they are to be used.

MOUNTING THE HEAD ON DESK TYPE TUBESTAND - After the arm 7, Figure "B", is mounted on the tube head, the assembly can be mounted on the vertical carriage. Do this by holding the head 5 with the arm pointed away from you and down at about 30 degrees. The arm can then be brought into position over and under the ears of the vertical carriage 3. For adjustment of head in horizontal plane, lift slightly on the head. Be sure that the head is not lifted so high as to disengage the arm from the ears on the vertical carriage. For adjustment of the head in the vertical plane, remove the head and shift the carriage to the desired position and lock before replacing the head. The 20, 25 and 30 inch focal distances are marked on the upright member. The indicated distance is correct when the white line on the vertical carriage corresponds to the line directly beneath the numerals.

MOUNTING THE HEAD ON PORTABLE-MOBILE TUBESTAND - Refer to Figure "C". Lock the stand to the floor by means of the two floor locks 23. Adjust the carriage 28 to a convenient height for handling the head. Move the arm in so the head end bumper 29 is against the carriage. Lock arm by tightening both thumb screws 16 and 14. In order that the pad on the yoke casting be held firmly against the bumper retaining cup 8, a means of adjustment has been provided. Two shim washers 34, Figure "F" are assembled under the cup. If the fit is too tight, one or both of these may be removed. If the fit is too loose, (two extra shim washers have been supplied) one or more must be added under the retaining cup. Do not add these shim washers on the outside of the retaining cup 8, Figure "F", otherwise they may be lost when the head is removed from the arm.

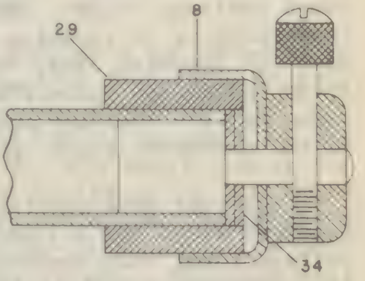


FIGURE F

MOUNTING THE CONTROL ON COLLAPSIBLE TUBESTAND - On some models the control is mounted on the stand as in Figure "A". On other models it may be placed on a convenient table or on the tube stand carrying case set on end. On the stand mounted models as in Figure "A", screw the upright or control support post 18 into the support bracket 19. The control bracket 20, Figure "A", is placed over the top of the support post 18 as shown. The control is then mounted on this bracket by hooking the control handle 21 over the control bracket 20, with the bottom of the control resting on the rubber bumpers in this control bracket.

MOUNTING THE HEAD ON PORTABLE-MOBILE TUBESTAND - Referring to Figure "C", a bracket 6 is supplied with the stand for mounting the control. It is held to the control by means of screws 30. The weight of the control holds the bracket in positive engagement with the gear racks 15, preventing it from falling. The control may be removed from the stand or placed at any convenient working height by simply tilting the control until the bracket becomes disengaged from the gear rack.

A timer hook 27 is also incorporated in the control bracket, providing a convenient place to hold the timer 26 when not in use.

A hook 4 has been furnished on the rear side of the carriage with which to fasten the control to tube head cable #1.

ALL UNITS - After the control has been mounted, attach the connecting cable to the shockproof head. The cable plug can only be put in the correct way, but be sure it is pushed in as far as it will go to insure good contact. Before attaching the line plug be sure the line voltage and frequency correspond to that marked on the nameplate of the unit.

OPERATION OF STYLE "C" CONTROL - Refer to Figure "A", turn filament control 23 to "O". Knob 22 functions as a main switch, a line voltage compensator and a kilovoltage control. When it is turned from the "OFF" position to any of the other nine settings, the filament of the x-ray tube should be lighted. This can be seen through the transparent window in the tube head if the filter is temporarily removed. If it does not appear to be lighted, turn the filament control to a higher setting. If it still does not light, note whether or not the voltmeter indicates the presence of voltage in the control. If it does not, recheck the line connection and the fuses at the line circuit. Be sure the knob 22 is definitely on the contact button and not in an intermediate or "OFF" position.

Assuming that the filament does light, turn control knob 22 to the settings marked "LOW" and then within this setting readjust it to the voltage setting corresponding nearest to the incoming line voltage. It will be noted that each of the three settings, "LOW", "MEDIUM" and "HIGH", are sub-divided into three groups, each corresponding to incoming line voltages. When this adjustment is set to correspond with the incoming line, the three settings of "LOW", "MEDIUM" and "HIGH" correspond to 40, 60 and 80 kilovolts respectively. This control is set to correspond with the incoming line when the pointer of the voltmeter most nearly coincides with the arrow on the voltmeter scale, when the load is on.

Whenever this control is set to a line voltage position higher than the actual incoming line, the kilovoltage is reduced. Whenever this control is set on a line voltage lower than the actual incoming line, the kilovoltage is increased. This is so proportioned that if the incoming line is 105 volts, it would be allowable to use all three settings in each group of "LOW", "MEDIUM" and "HIGH". When it would be set on 105, the kilovolts would be exactly 40, 60 and 80, depending upon the setting of "LOW", "MEDIUM" and "HIGH". If it was set on 115, the kilovolts in each bracket would be reduced by 5 or would then be 35, 55 and 75. If it was set on 125 volts, another 5 kilovolt reduction would be made and the output would become 30, 50 and 70 kilovolts. If instead of this the incoming line was 125 volts, it would be allowable to set the knob 22 in any of the positions under "LOW" or "MEDIUM". *But on "HIGH" it would not be allowable to set it anywhere except on 125.* This, as explained before, is because the voltage would then be increased beyond 80 kilovolts, which is the maximum rating of the unit; at most installations the incoming line voltage is lower than 125 volts. Therefore, in the average installation, knob 22 serves as a kilovolt adjuster in steps of 5 Kv.

THIS UNIT SHOULD NEVER BE OPERATED ON "*HIGH*" WITH THE LINE VOLTAGE ADJUSTMENT SET SO THAT THE POINTER OF THE VOLTMETER IS ABOVE THE ARROW ON THE VOLTMETER SCALE WHEN THE LOAD IS ON.

OPERATION OF STYLE "F" CONTROL - Refer to Figure "B". Turn filament control knob #10 to number 25 on the dial. Set the selector switch 12 on the lowest auto transformer tap #1 on the nameplate. Then turn on the main switch 11. The red pilot light on the control should light. The filament of the x-ray tube should be lighted. This can be seen through the transparent window in the tube head if the filter is temporarily removed. If it does not light, recheck the line connection, the fuses in the line circuit, and the connection between the transformer to control at the connection plug on the tube head. Exposures may be made with a push button or hand timer which is plugged into the receptacle on the side of the control.

THIS UNIT SHOULD NEVER BE OPERATED WITH THE LINE VOLTAGE ABOVE 130 VOLTS. IT SHOULD NEVER BE OPERATED ABOVE 15 MA NOR LESS THAN 2 MA. The selector switch steps represent approximately 6 Kv.P at 5 MA, 10 MA and 15 MA. At line voltages above 125, only step 1 or 2 may be used. If higher steps are used, the needle of the voltmeter will be above the arrow printed on the voltmeter scale and there will be excessive voltage on the x-ray tube.

REMOVAL OR REPLACEMENT OF X-RAY TUBES - Access to the tube is made possible without removing the main cover of the shockproof head. This is accomplished by removing the cover plate 27, Figure "A". This must be done with the head in such a position that this cover plate is up and the head stands square so that oil will not be spilled as the cover is removed. Complete instructions for removing or replacing an x-ray tube are contained under the cover 29, Figure "A".

It is extremely important that the unit be completely filled with oil and that no air bubbles remain. Care must be exercised so as not to lose oil during the exchange of tubes. If any oil is lost, it is permissible to add any highly refined clear medicinal oil, providing it is taken from a fresh container and is *absolutely free from moisture and foreign materials.*

ROTARY CONVERTER FOR USE ON DC LINES - This unit is mounted on rubber pads to absorb vibration. To secure long life of these rubber pads or feet, they must be kept free from oil. Therefore, when oiling the bearings, care should be taken not to use an excessive amount of oil. The "ON" and "OFF" switch on the cover of the automatic starter, mounted on one end of the rotary, is for the operation of the automatic starter. The selector switch 22, Figure "A" should be on the "OFF" position when starting the rotary. The line connecting cord should be installed in the male receptacle on the rotary and the cord with the plug, attached to the control, should be plugged into the female receptacle on the rotary. The plug will only fit one way so no mistake can be made at this point. However, it is extremely important that the voltage of the supply line be correct for the rotary in use. Under no circumstances should the unit be connected to 220 volts if it is a 110 volt rotary, and if it is a 220 volt rotary the unit will not work if connected to 110 volts.

A.C. - D.C. CHANGEOVER SWITCH - There is available another model of rotary converter with provisions for operating the unit on either DC lines or AC lines. A switch is provided on the automatic starter, which in one position changes the circuit so that, for DC lines, the converter will operate through the correct circuit; and for AC lines the rotary converter is out of the circuit, the control is connected directly to the line cord, and the circuit is correct for operation on AC. It is extremely important that the switch be set on the correct side. Under no

circumstances should the switch be set on the AC position if the line cord is connected to DC. This type of unit requires but one line cord whether it is operated on AC or DC. In all cases the line cord is provided with a ground clip. This should be connected to the ground or earth connection, although protection from high voltage shock is provided whether or not this precaution is used. It is best, however, to make the ground connection as this provides protection against low voltage shock that might otherwise occur under certain conditions.

POSSIBLE OPERATING DIFFICULTIES

If the voltmeter does not indicate, make sure:

1. That the line cable is properly plugged into the receptacle of the supply line.

2. That there is voltage at this source of supply.

3. That there is no break in the conductors within the line cable. This is apt to occur at or near the point of connection of the plugs.

4. That the kilovoltage selector switch is not set midway between two buttons or is on the "OFF" position.

If the milliammeter does not indicate:

1. Remove the cone and filter to see if the x-ray tube filament lights.

2. Examine the plug of the control cable at the shockproof head. Be sure that it is properly inserted and that no wires are broken off. This can be determined by slightly flexing the cable near the plug with the idea that if a wire is broken, its ends may be brought in contact by flexation, temporarily lighting the filament.

3. Make sure that the timer or footswitch is properly plugged into its receptacle and that good contact is established at this point.

4. It may indicate a defective meter. Either have the meter checked or substitute a new meter.

If milliammeter indicates but fluctuates:

1. Slight fluctuation may be expected because of line voltage changes. It may also indicate loose connections within the unit or in the supply line, but in most cases at the connecting plug or line cord.

2. If the milliammeter fluctuates severely it may indicate a loose connection in the filament circuit of the x-ray tube, possibly at the point of contact between the tube holder and its connection to the filament lighting transformer. The x-ray tube will have to be removed to correct this. It is not likely to occur and all other conditions should be checked first.

3. Severe fluctuation of milliamperage may indicate a gassy x-ray tube. If all other points have been checked and the tube removed, and it shows melting of the copper anode or traces of oil inside the tube, it is safe to assume that the tube is gassy and was overheated through prolonged exposure.

4. If the milliammeter moves a division or so and then vibrates severely, it indicates that the x-ray tube is bad, probably very gassy.

EXPOSURE RATING:

1. Maximum length of exposure at 15 MA with target starting at room temperature is 10 seconds.

2. Maximum length of exposure at 10 MA with target starting at room temperature is 30 seconds.

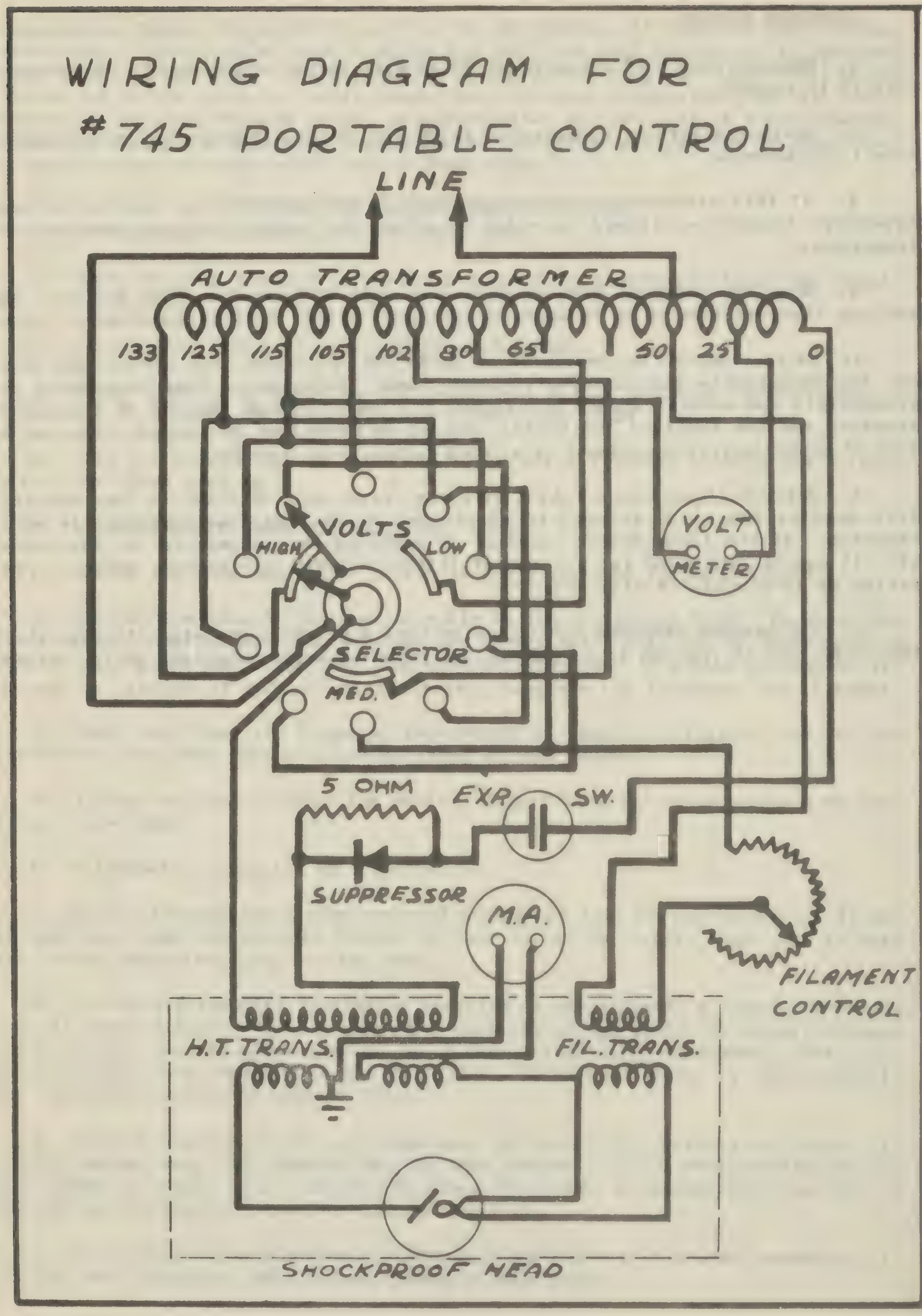
3. If this exposure is to be repeated, an interval of five minutes between exposures should be allowed in order to allow the target to cool down to room temperature.

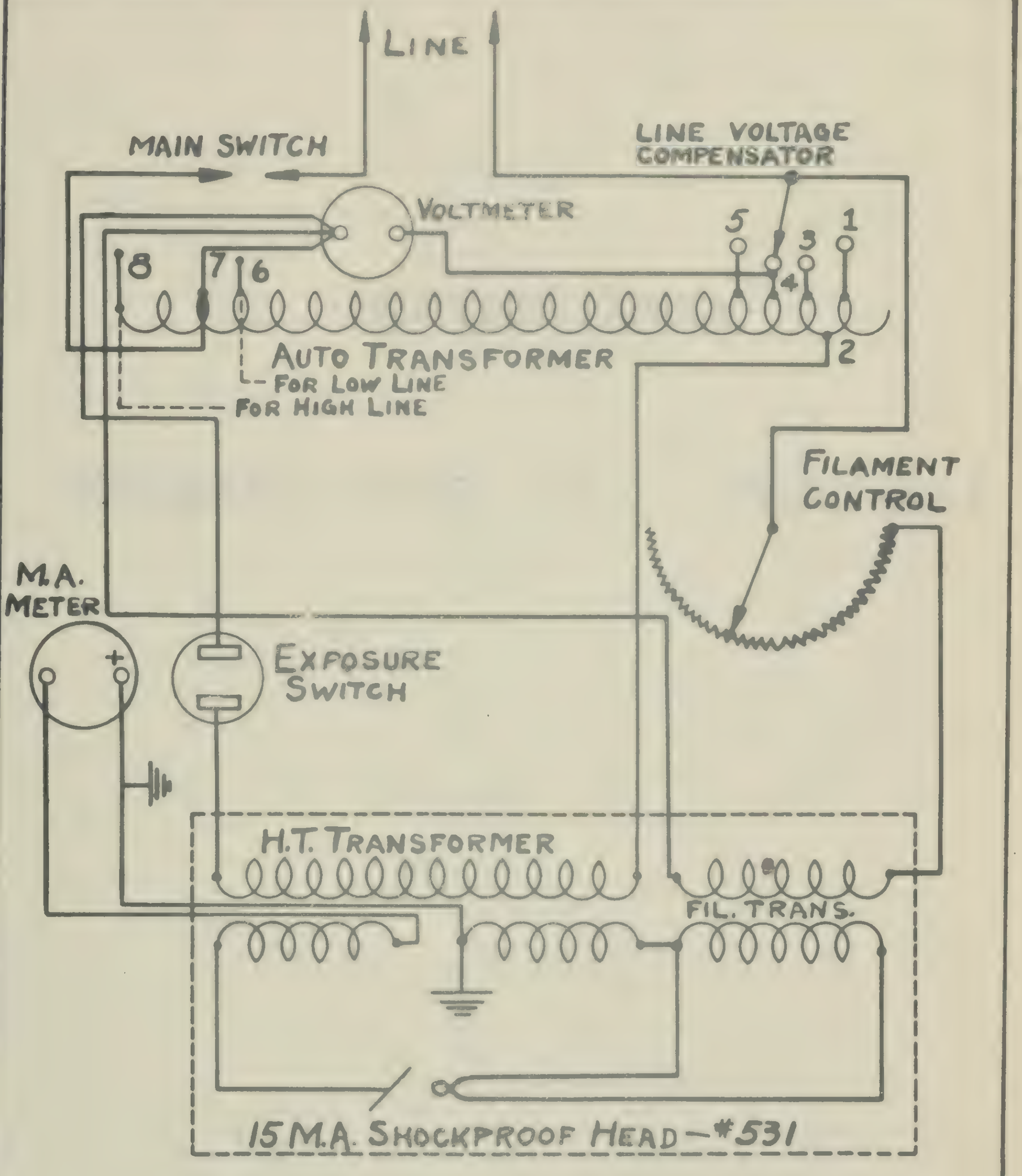
4. When the interval between exposures will be less than five minutes, the maximum exposure should be reduced accordingly, either in milliamperage or time.

5. As an example, two exposures of 10 MA for 15 seconds each may be made without any appreciable time interval between them. In making a third exposure, approximately two minutes should be allowed to elapse between the end of the second exposure and the start of the third. Two 10 MA exposures 20 seconds long may be made if approximately one minute is allowed between each exposure.

6. Maximum fluoroscopic rating with the target cold is 5 MA for four minutes. Five minutes should be allowed to elapse before this maximum exposure is again repeated. If the fluoroscopic exposure is operated for one minute on, one minute off, it may be continued for a total of fifteen minutes of exposure before a rest period of 10 minutes is desirable.

7. The maximum exposure should not be used when the cover plate through which the x-ray tube is removed is on top and the rotation scale nameplate on the bottom.


WIRING DIAGRAM FOR
#745 PORTABLE CONTROL
LINE
AUTO TRANSFORMER
133
125
115
105
102
80
65
50
25
0
VOLTS
HIGH
LOW
VOLT
METER
SELECTOR
MED.
5 OHM
EXP. SW.
SUPPRESSOR
M.A.
FILAMENT
CONTROL
H.T. TRANS.
FIL. TRANS.
SHOCKPROOF HEAD



WIRING DIAGRAM for #778

MODEL "PF" PORTABLE CONTROL

SECTION XXXI

KELEKET TYPE - 80 C - PORTABLE

KELEKET TYPE "80-C" PORTABLE

INSTRUCTIONS FOR INSTALLING AND OPERATING

UNPACKING - Care should be taken in unpacking and handling so as not to damage any parts. Check and examine all packing cases so as not to overlook any small parts in packing material. Should there be any parts damaged, notify the Medical Supply Officer at once.

Special care should be given to the handling of the Self Contained Energizing Tube Head as the X-Ray Tube and High-Tension units are mounted therein.

ELECTRICAL OUTLET - The Deluxe "80-C" Portable Unit is calibrated for 5, 10 and 15 milliamperes between 30 and 80 Kilo-Volts peak. Calibration was accomplished with tube under load employing a 70 foot run of #14 wire between the 110 Volt 60 Cycle A.C. *mains* and *base plug receptacle*. The Prereading Kilo-Volt Meter calibration may be depended upon, providing the portable unit is connected at all times to the standard #14 wire base receptacle.

The #14 line should be protected by 30 ampere fuses whenever 15 Milliampere current load is to be drawn across the tube head. 20 ampere fuses will be proper for 10 M.A. and 10 ampere fuses for 5 M.A. load. (DO NOT CONNECT THIS PORTABLE TO HEAVIER 110 VOLT 60 CYCLE A.C. POWER FEEDERS THAN ABOVE INDICATED.) The line voltage compensator will correct for line voltages between 96 and 129 volts.

The parts for the "80-C" Portable are arranged to be conveniently transported in three carrying cases.

CASE #1 - This case includes the Control Unit containing the Auto Transformer, Connecting Panel with fuses, Timer Plug outlet, Meters and Regulators. A separate compartment beneath the control proper holds the Interconnecting Cable with the pronged end multiple plug and a standard length Inlet Cable with *Ground* Connection to be extended to water pipe or *grounded conduit* receptacle plate. A removable latched cover plate fits flush over this rear compartment opening. A hinged protective control cover, double latched at the front of control case proper, with carrying handle centrally located allows the unit to be readily transported. The weight of this particular unit approximates 36 pounds. Proper Technique chart is inserted into control cover for ready reference.

CASE #2 - This leather zipper case will include the Self Contained Oil Immersed Transformer and Tube Head in center partition while the two end partitions will accommodate the 1/4 to 12 sec. Hand Timer with plug connection and Master Adapter Cone which accommodates a full set of Brass Reducer Diaphragms, namely, #5, #7, #9, #12 and #15. These diaphragms will cover the corresponding radiographic field in inches at 30" T.F. Distance as indicated by the diaphragm number. The Master Adapter Cone which is fastened to front of tube head by two thumb screws, is designed to cover full 20" diameter active field at 30" distance of its own accord. Weight of self contained head approximates 37 pounds.

CASE #3 - This package will include the dismembered portable tube stand upright with folding extension legs, clutch handle ratchet lift and stereo carriage suspension. Proper straps with carrying handle allows a convenient means for transportation. The approximate weight will be 33 lbs.

ASSEMBLY - It is suggested that the portable tube stand members be first unstrapped and assembled.

The upright standard should be manipulated to a vertical position with folding legs at the bottom. Loosen the wing bolt in sleeve which slides over upright member. The legs attached to this sleeve should be fully extended and wing bolt tightened against upright member for stability. The horizontal carriage rider bar

and top support casting with ball bearing riders should be recessed over top of tube stand upright. Unlatch clamp at end of horizontal carriage bar, throwing it back out of the way to receive the tube head yoke member. The end tube carriage swivel bearing terminating in yoke clamp member should be tightened to carriage bar before properly recessing tube yoke member, then lever latch should be thoroughly tightened so that tube head will not drop out of the yoke clamp when head is inverted.

Before mounting tube head to carriage bar it is wise to loosen clamp located at one side of tube head proper, then swing yoke to one side and clamp in a convenient position for lifting and manipulating yoke into yoke clamp member. (The connection plug on tube head should be to the rear.)

TUBE MANIPULATION - It will be noticed that the horizontal carriage bar may be moved in and out over the patient and that the bar may be clamped by set screw located at the front of rider frame. Tube Head may assume any angle lengthwise of patient and swivel joint allows 360° motion of tube head at this point. Swivel clamp arrests this motion. For lateral angulation across the patient, the yoke may be unclamped at the tube head.

STEREO-SHIFT - Between the two sets of ball bearing carriage riders will be found a stereo spacer piece with central clamp. In lateral stereoscopy, the tube is aligned centrally over part then stereo spacer clamped in a central position. One exposure is made at each *stereo motion limit.* A stereo cassette tunnel will be necessary to allow cassettes to be changed beneath patient so as not to disturb alignment of part. When diaphragms are employed, then the operator must angulate back to center on each shift to allow diaphragm field to be projected centrally in each of the stereo exposures. If the adapter cone is employed without a diaphragm for head work then the exposure must be decreased to at least 60% of that indicated in technique chart.

For Vertical 48" P.A. Chest stereoscopy, two complete turns of the elevating crank allows proper 5" shift whereas for 30" distance, one complete turn may be employed.

CONTROL UNIT - The small rear control housing panel should be removed and interconnecting control cable should be properly connected to tube head housing by special multiple plug instituted for the purpose. The hand timer cable plug terminal should be inserted at the right of control and twisted in a clockwise direction to lock. A foot switch may also be connected in place of the timer when found convenient.

Your attention is drawn to blue print wiring diagram B-71684-4 which indicates control members and connection REAR VIEW. Therefore the location of members denoted on blue print is reversed from what is perceived at the control top.

The control panel includes the following members:

M.A. METER - This D.C. Milliampere meter is located at top left hand corner and reads from 0 to 15 M.A. It will be noted that it receives its current from the mid-secondary terminals on connection panel marked "G" (ground) and "M".

K.V. METER - This Kilo-Volt meter is located at the top right and shows a reading from 0 to 90 PRE-READING KILO-VOLTS but has a red line tube limit at 80 K.V.P. point on scale. This red line is also employed to preset line voltage compensator.

LINE COMPENSATOR - The line voltage compensator has a *twelve* step auto regulation and allows the unit to be standardized between line voltage variations of 96 to 129 Volts. This regulator is located between the two meters.

MILLIAMPERES - This member is in front of the Milliampere meter, the reading of which it controls thru the regulation of the X-Ray tube filament temperature. The control is turned clockwise to increase the Milliampere reading.

VOLTAGE SELECTOR - This is a *twelve* step auto transformer adjuster for obtaining proper variation in X-Ray tube penetration and controls the reading of the Kilo-Volt meter. A total of 24 steps of kilo-voltage regulation is allowed thru the HI-LO toggle.

MAIN - This toggle is a combination double pole, double throw switch with center "OFF" position. The switch acts as a main control switch and as a multiplier. When thrown to "LO", the 12 step voltage selector is controlled thru auto tap "36" and when moved to "HI" the voltage across this selector is increased by change of auto tap to Auto "O" allowing an additional 12 consecutive steps of regulation thru the manipulation of *Voltage Selector* starting again in a counterclockwise position and advancing clockwise.

PUSH - This double pole, double throw push switch *when depressed* answers the purpose of disconnecting the K.V. Meter potentiometer circuit and places this meter across auto taps "O" and "99" so that the unit may be standardized thru the manipulation of the line voltage compensator. The line compensator is turned until needle of K.V. meter points to red line at position indicating "80" on meter whereupon the push switch is released reconnecting potentiometer circuit.

TECHNIQUE - This selector reads 0, 5, 10 and 15 and is a variable potentiometer contactor. We recognize that an increasing tube current in Milliamperes means an increased voltage drop under load. The potentiometer circuit furnishes a bucking voltage across the meter and may be adjusted to automatically compensate for this voltage drop for the particular tube loading to allow the K.V. meter to accurately preread the K.V.P. values. The potential furnished across this potentiometer originates from a separate winding on the auto transformer with auto taps designated by prefix "T" in front of voltage tap indicated. Potentiometer adjustment is made by repositioning the several straps in connection with the resistor in this circuit. Calibration chart included with instructions controls this adjustment. This calibration specifies that "80-C" portable installation should be made in connection with 70 Ft. run of #14 wire on voltages averaging 110 Volts 60 Cycle A.C. or its equivalent.

TIMER - The timer supplied is a mechanical unit where the indicator should be definitely set to control the exposure. Time range is 1/4 sec. to 12 sec. where 1/8 sec. may readily be derived. While setting timer, there will be noted a definite clicking sound of the ratchet. The first click will not set the timer but two clicks represents 1/8 sec., 3 clicks = 1/4 sec., 4 clicks = 3/8 sec., etc. This type of timer may have its indicator moved back over scale to correct for exposure setting. On very short exposures, move back to zero release and then reset. The timer push switch *when completely depressed* starts timer mechanism and exposure. When push button is not thoroughly depressed, the surge resistor is left in the primary circuit and proper Milliamperage and voltage will be lacking, thus proper radiographic density will be lacking. An exposure may still be accomplished by depressing push button even though the indicator has not been moved off zero position. This idea allows switch to be employed for 3 to 5 M.A. fluoroscopy instead of foot switch which may be plugged into same connection as the timer at right of

control. Plug should be turned to right to lock.

Always set timer indicator in checking or exposing radiographically so as to keep notation of exposure to compare with normal tube rating which should not be exceeded.

"CYM" X-RAY TUBE - The focal spot in this tube is 1.5 mm. square in projection. Maximum anode temperature is obtained under radiographic procedure in 40,000 units which represents (K.V.P. X M.A. X Seconds). The maximum single exposure rating of the "CYM" Tube is 5 M.A. 80 K.V.P. for 3 minutes, 10 M.A. 80 K.V.P. for 48 seconds and 15 M.A. 80 K.V.P. for 12 seconds, therefore these values must not be exceeded at any time.

After an exposure of 15 M.A. 80 K.V.P. 12 sec. a minimum of 5 seconds rest period should be allowed before repeating such an exposure.

No more than *three* such exposures should be repeated in rapid succession with the above 5 sec. rest period. About *one minute* cooling intervals should be allowed *after each exposure*, if they are to be repeated on a continuous basis. (DO NOT DEVIATE FROM THESE INSTRUCTIONS). (OVERHEATING MAY DAMAGE AND CRACK THE FOCAL AREA WHICH WILL CAUSE OPERATOR TO INCREASE NORMAL EXPOSURE BY 50% THUS CAUSING FUZZY RADIOGRAPHS AND FINALLY THE DESTRUCTION OF THE TUBE).

CONNECTION PANEL - This panel is located inside and towards the front of control.

FUSES - Two 30 ampere fuses are employed to protect the unit.

MAIN - These two terminals are the power inlets for the 110 Volt 60 Cycle A.C. current. Normally this cable is carried in compartment below control proper.

F & F - These terminals supply the energy for X-Ray tube primary filament circuit.

X & Y - These terminals supply the power for the X-Ray transformer primary.

M & G - These connections extend from the D.C. Milliampere meter on Control panel to the mid-secondary points of X-Ray Transformer. G is the grounded side and is tied into connection with transformer cores, control case then extended to proper conduit base receptacle or direct to water pipe ground thru a third wire in the inlet extension cable.

FUSE REPLACEMENT - We do not anticipate any overloading of these 30 M.A. fuses. Should a replacement be necessary, then screws from top of control must be removed and tie limit rod between cover and control must be unpinned. (It is assumed that inlet cable has been disconnected from power receptacle.) The tie rod must be dropped into control case and control lifted from inclosure. (Handle by means of *control plate* and *not the engraved top plate.* Reverse procedure after fuse replacement but remember to replace tie limit rod before seating control plate.

TUBE REPLACEMENT - Should a Tube replacement ever be necessary, the entire tube head should be exchanged.

ADAPTER CONE AND DIAPHRAGMS - The Adapter Cone which always limits the active radiographic field at 30" Dist. T.F.D. to 20" Diameter is always employed unless technique states, "NON". The several diaphragms are inserted at the end of this

adapter to reduce the size field at 30" Dist. to 5", 7", 9", 12" and 15" depending upon the numbers stamped on the diaphragm members.

TESTING - It is assumed that the "80-C" Unit has been assembled properly and the inlet cable connected to the recommended base receptacle ready for operation. Proper ground wire is to be instituted before operation.

#1 Set "MILLIAMPERES CONTROL" and "VOLTAGE SELECTOR" to a minimum by turning counter-clockwise.

#2 Throw "MAIN" switch to "LO".

#3 Set "TECHNIQUE" Selector on 5 point.

#4 Depress "PUSH" switch on control while the "LINE COMPENSATOR" is revolved back and forth until needle of "PEAK KILO-VOLT METER" reads to *red* line or at 80 K.V.P. position, then release "PUSH" switch which will allow kilo-volt meter to accurately preread 5 M.A. tube load.

#5 Set "TIMER" for 10 seconds.

#6 Depress *timer push button* on top of hand unit and at the same time move "MILLIAMPERES" selector clockwise until the D.C. Milliampere meter reads 5 M.A. then release timer push button.

#7 Notice that K.V. meter prereads a definite Kilo-voltage and when "VOLTAGE SELECTOR" is turned step by step clockwise that the K.V.P. reading increases.

Return this voltage selector to a minimum then throw MAIN switch to "HI". The K.V.P. reading now will be one voltage step above "LO" - #12 auto voltage selector step and now will advance by clockwise motion until 24 steps total regulation has been accomplished. (DO NOT TURN EITHER THE "VOLTAGE SELECTOR" OR "LINE COMPENSATOR" WHILE TIMER PUSH BUTTON IS DEPRESSED BECAUSE ARCING AT THE CONTACTS WILL DESTROY ELECTRICAL EFFICIENCY OF THE UNIT).

#8 Turn voltage selector still on "HI" back to minimum, then turn technique selector to 10 then to 15 and notice Kilo-volt meter reading drops off each time but giving true reading proper for increased tube load.

#9 Now with Technique selector on 15, set timer for 1 second and depress timer push button while Milliamperes control is advanced to show 15 M.A. reading on D.C. Milliampere meter. Timer may have to be reset to one second several times to obtain exact 15 M.A. but the Milliamperage setting should be tested always on such a setting as "HI" #1 voltage Selector so as not to overheat the tube. This M.A. setting should not change perceptibly over the entire range of 24 auto steps. Do not go above a reading of *80 K.V.P.* at any time.

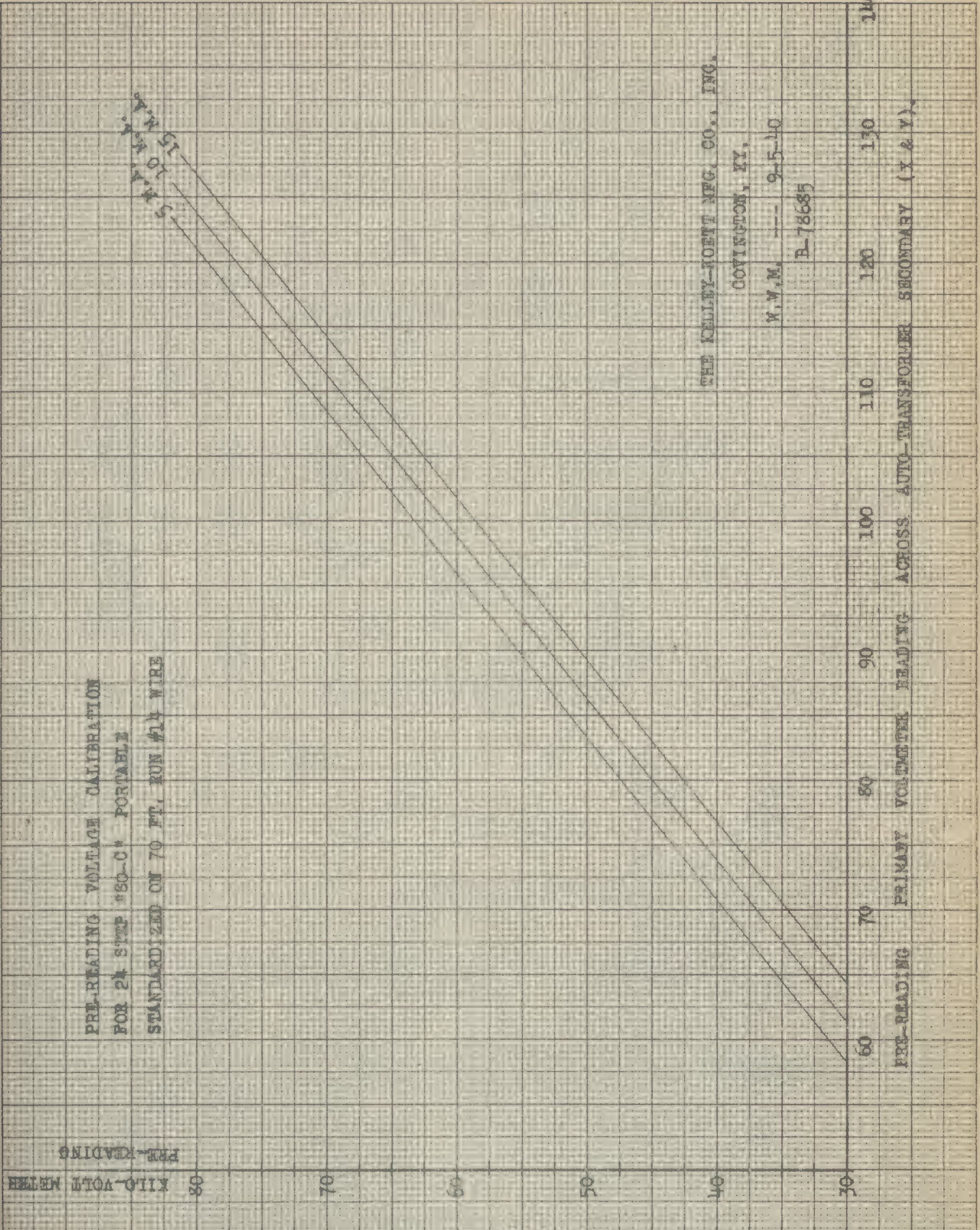
Test for 15 M.A. at 80 K.V.P. setting timer at one second.

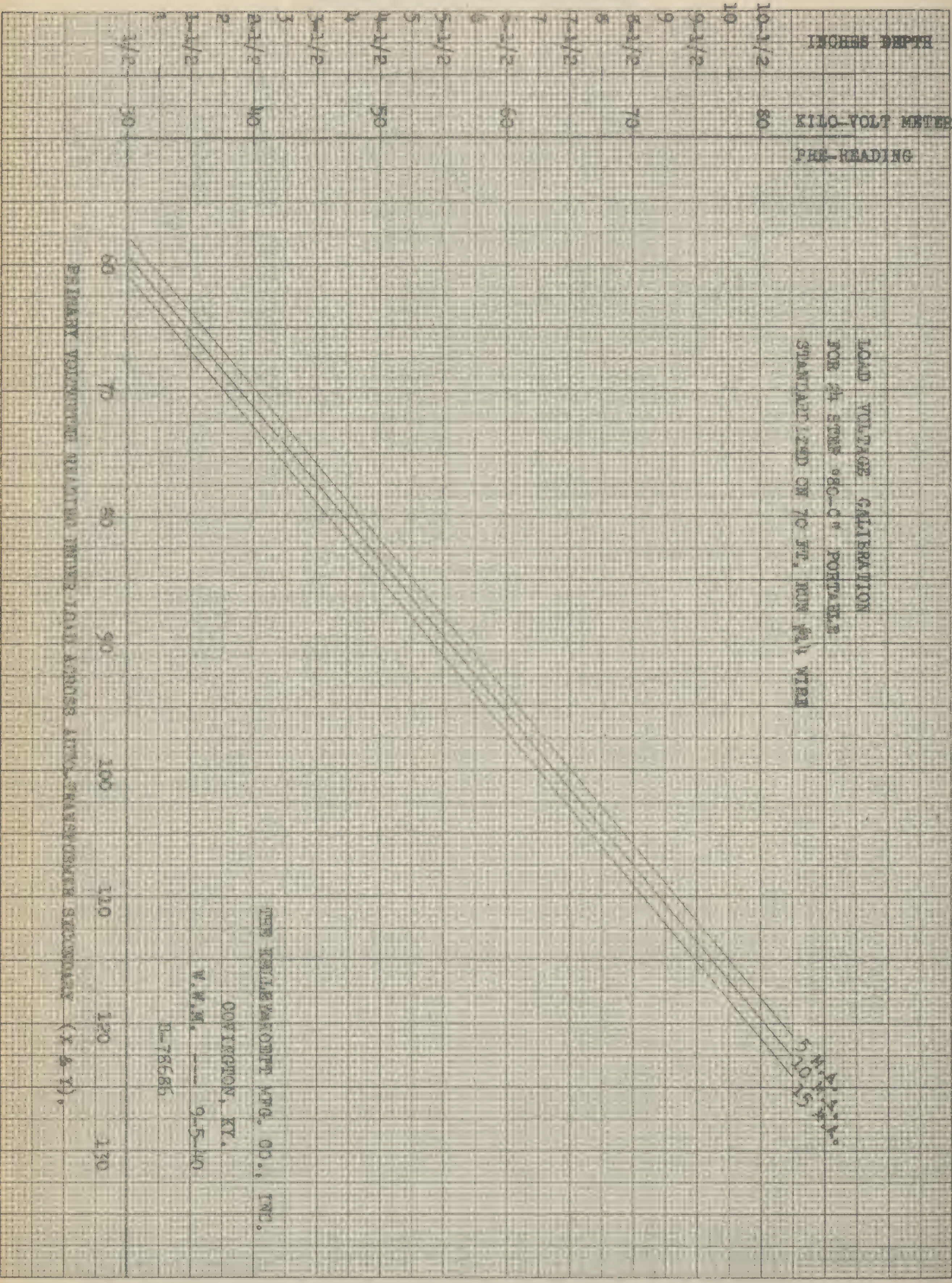
CALIBRATION TEST - A PREREADING VOLTAGE CALIBRATION CHART is included with all instructions showing the Prereading primary voltage reading across terminals (X & Y) for different Kilo-voltage readings across the Prereading Kilo-voltage Meter on Control panel. Whenever these comparative readings are checked against the factory calibration an accurate volt meter should be employed. The factory calibration should check accurately unless some damage has been incurred during transportation. There are two convenient methods of connecting the test volt

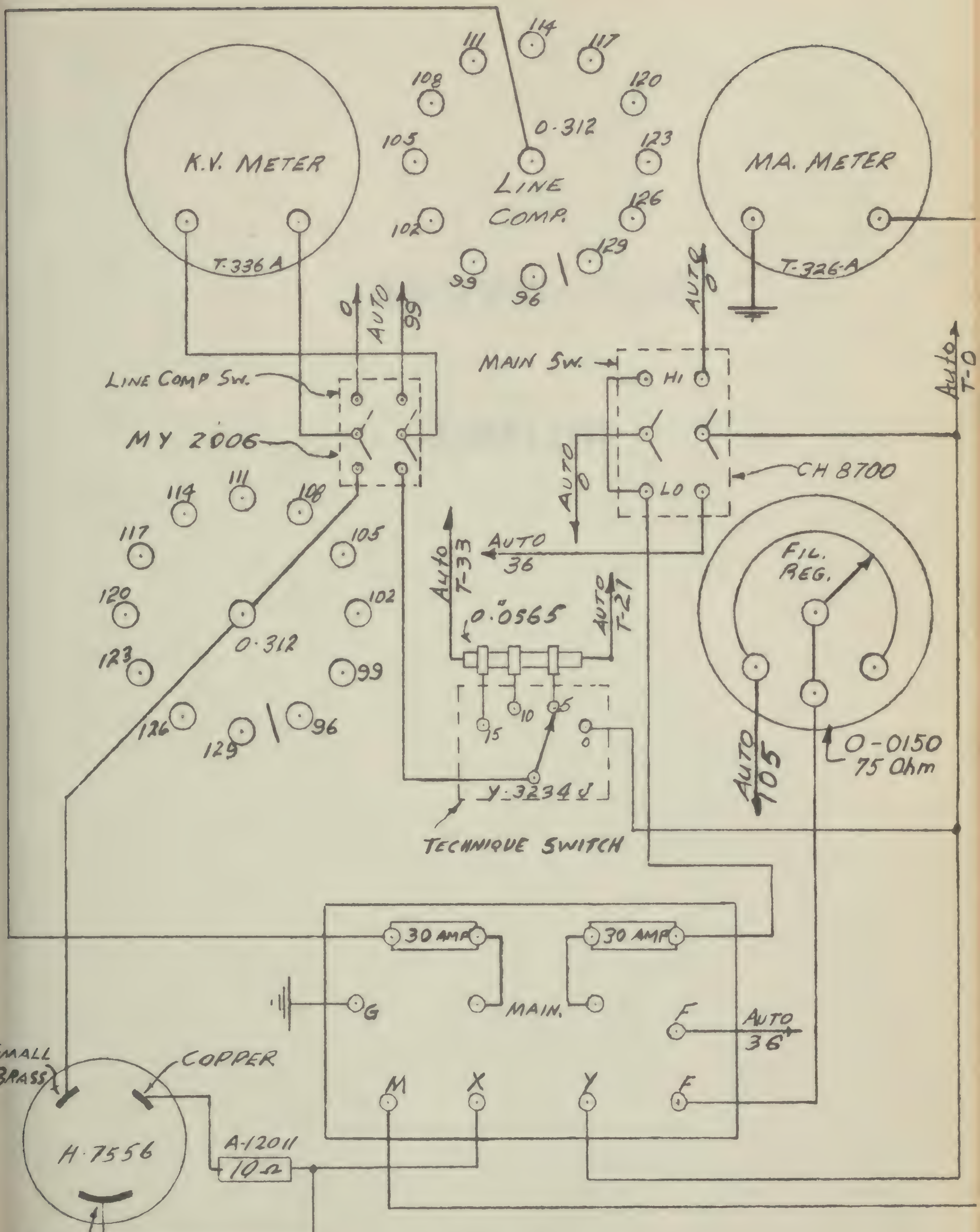
meter, the first being, to unplug the multiple plug from the head and plugging the meter wires into female clips of X and Y. These X and Y clips are determined by viewing entrance of six way female connection, having member turned so that *polarized pin hole* is located to the *right* of *center*. Now X and Y clips are #1 and #2 in top row from left to right. The Timer push button must be depressed to obtain these prereadings. The other method is to remove cover plate from terminal block at tube head and disconnect wires X and Y and extend to volt meter for testing calibration. The multiple plug must be connected together before testing. THIS PREREADING CALIBRATION IS PROPER FOR AVERAGE #14 LIGHTING LINES OF 70 FOOT RUN.

It will be noted that, when Technique Switch is set on 5 and auto regulation gives 50 K.V.P. at Control prereading K.V.P. Meter, the prereading primary volt meter should read 83-1/2 volts. Changing Technique switch to 10, the primary volt meter should read 87-1/2 volts when auto regulator is arranged to allow 50 K.V.P. at control meter. The factor for 15 setting will be 89-1/2. A 70 K.V. prereading K.V.P. meter check may be accomplished for Technique switch settings for 5, 10 and 15. A change in position of straps on Technique Switch potentiometer resistor will allow K.V.P. meter to match proper prereading primary voltage. If however, there is a deviation of 1/2 volt either way, it will not materially change the end radiographic result.

Hereafter you will find a standard LOAD VOLTAGE CHARTING against PREREADING K.V.P. CONTROL METER reading. Although the first chart tests accurately the factory potentiometer settings, this chart allows the serviceman to install the portable unit on any particular power line other than the factory standard. Change in the TECHNIQUE potentiometer setting for 5, 10, and 15 milliamperes may be accomplished to allow the load voltage values to match proper prereading at K.V.P. control meter. In this case, the volt meter is read directly across (X & Y) at tube head connection block with X-Ray tube operating under load. Two points on each curve will suffice, for instance 50 K.V. and 70 K.V. points.


PRE-READING VOLTAGE CALIBRATION
FOR 24 STEP "80-C" PORTABLE
STANDARDIZED ON 70 FT. RUN #14 WIRE
THE KELLEY-KOETT MFG. CO., INC.
COVINGTON, KY.
W.W.M. --- 9-5-40
B-78685
15 W.Y.
10 W.Y.
5 W.Y.
60 70 80 90 100 110 120 130 140
PRE-READING PRIMARY VOLTMETER READING ACROSS AUTO-TRANSFORMER SECONDARY (X & Y).
KILO-VOLT METER PRE-READING
30 40 50 60 70 80
INCHES DEPTH
1/2 1 1-1/2 2 2-1/2 3 3-1/2 4 4-1/2 5 5-1/2 6 6-1/2 7 7-1/2 8 8-1/2 9 9-1/2 10 10-1/2


LOAD VOLTAGE CALIBRATION
STANDARDIZED ON 70 FT. RUN #14 WIRE
INCHES DEPTH
KILO-VOLT METER
PRE-READING
5 M.A.
10 M.A.
15 M.A.
COVINGTON, KY.
W.W.M. --- 9-5-40
(X & Y).


K.V. METER
T-336 A
MA. METER
T-326-A
111
114
117
108
120
105
0-312
123
LINE
COMP.
102
126
129
99
96
AUTO
0
AUTO
99
MAIN SW.
HI
LO
CH 8700
Auto
T-0
LINE COMP SW.
MY 2006
114
111
108
117
105
120
102
123
0-312
99
126
129
96
Auto
T-33
AUTO
36
AUTO
T-21
0-.0565
15
10
5
0
Y-3234 J
TECHNIQUE SWITCH
FIL.
REG.
AUTO
105
O-0150
75 Ohm
30 AMP
30 AMP
G
MAIN.
F
AUTO
36
SMALL
BRASS
COPPER
M
X
Y
F
H-7556
A-12011
10 Ω
LARGE
BRASS

REAR VIEW

SECTION XXXII

AIRFLOW

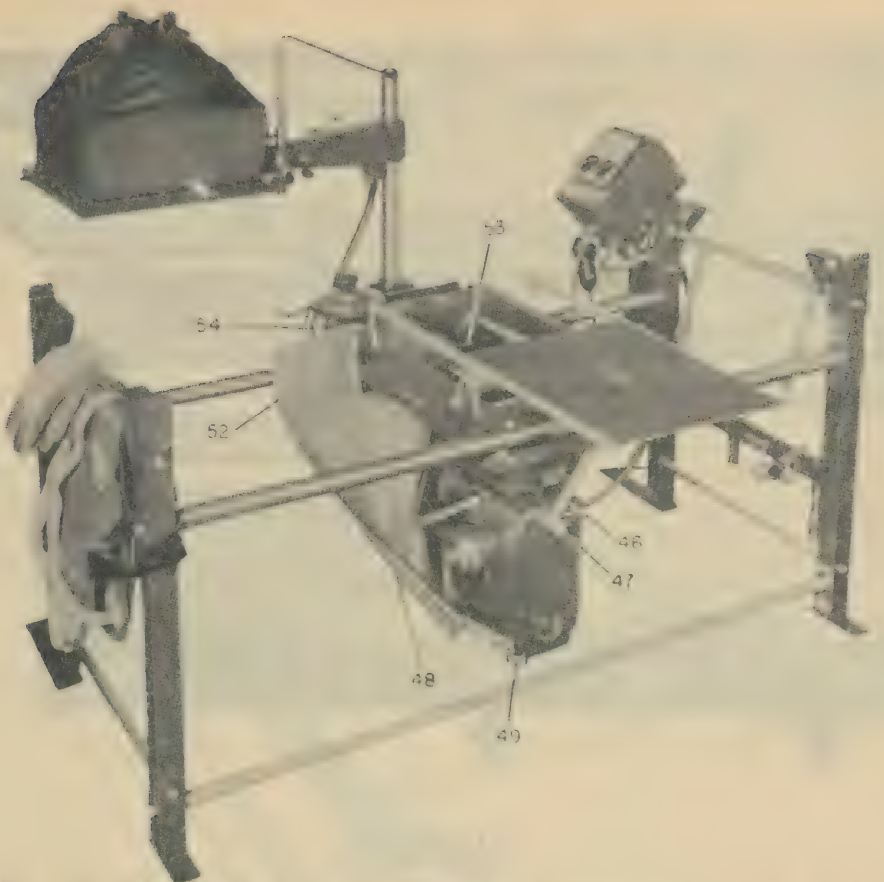


FIG. A

X-RAY FIELD TABLE OF ITEM NO. 96215

This table, Figure A, has been designed to save weight and bulk. In doing this it has been necessary to sacrifice some flexibility. It, therefore, is not practical to use for vertical fluoroscopy. It will, however, handle horizontal fluoroscopy, foreign body localization, horizontal and vertical radiography in a convenient manner.

Care should be exercised in unpacking to make mental note of the simplicity of packing, and yet at the same time realize that it will not pack into the space provided unless the parts are returned to exactly the correct positions. Each of the four legs are hollow, and are intended for storage of the various tubular members required in the framework of the table.

ASSEMBLY OF TABLE FRAME - It will be noted that there are four larger diameter tubes which, when properly assembled, form the main rails on which the horizontal carriage travels. Two of these members have attached to them a section of gear rack. One each of these four tubular sections are telescoped within each leg. It will also be noted that a smaller diameter tubular member is provided, made of two sections that join the two table legs together from end to end near the bottom of the legs. These two members in turn telescope within the tubular members referred to as the main rail for the carriage. Then there are four more smaller diameter tubular members used to join the upper and lower ends of the table legs and used at the ends of the table. These in turn telescope within the last mentioned members. Provision is made in Chest No. 1 for the packing of the

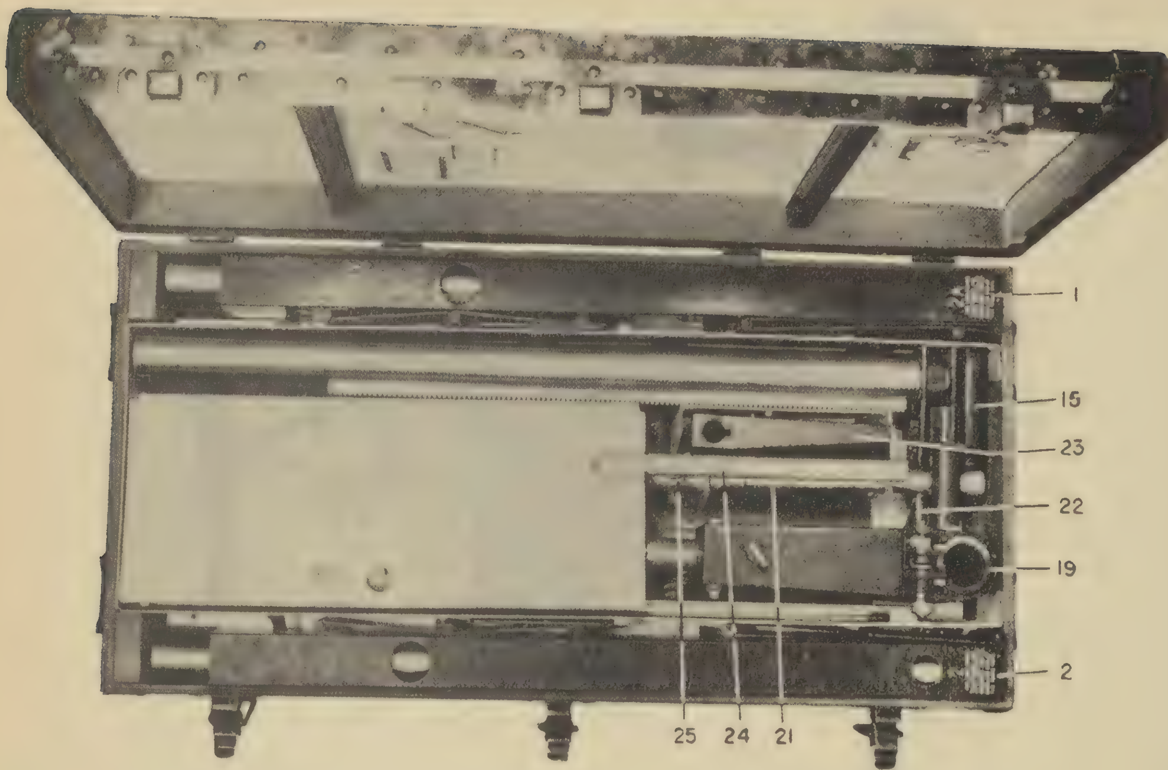


FIG. B

six draw bolts, This is a vertical compartment, open at the top and next to the partition for the leg assemblies in the front of the chest. To simplify the assembly and repacking, a color code and instructions are used on each leg and each tubular member. If care is observed to join like colors together, as indicated on the printed instructions found on the parts themselves, there should be no difficulty in assembling the table.

Hinged members are provided at each end of the table legs which serve as a collapsible means (for purposes of packing and ease in assembly) of obtaining a support for the litter, and also to increase the bearing area of the legs to prevent sinking of the table in soft ground.

It is best to assemble the end sections of the table first, using the 3/8-24 x 1" hexagon head cap screws to hold the cross rails to the legs. These screws and the wrench will be found in the small compartment within the tool box welded to the horizontal carriage in Chest No. 2. To open the tool box it will be necessary to slide the shelf of the cassette tray to the left as you face the open chest. Therefore, remove the four leg assemblies, two of which lie in each compartment in the Chest No. 1, and remove all of the tubular members found telescoped within them. Take one pair of leg members, as for instance the two marked "2" and "2-A", at their extreme lower extremity. These should have the yellow and blue color coded instructions No. 1 and No. 2, Figure B. Fold the hinged plate welded at the bottom of the "blue" leg No. 2, Figure C, so that it lies below the leg as at (3), Figure C, to increase the area of contact with the ground. Illustrated instructions are attached to each hinged member. Now fold the hinged plate beneath the bottom of the leg having the yellow color coded instructions No. 1, Figure C, and return it to the

FIG. C

side of the leg so that the hole in the outer extremity of this member aligns a corresponding hole in the leg as at (5), Figure C. Insert the small cross rail (4) with the yellow color coded instructions into the yellow leg, and insert a hexagon head cap screw through the hole of the hinged plate and the table leg, and thread it into the cross rail as at (5). At the top of this leg, fold the upper hinged plate over the top of the leg until the plate with the hole aligns with the hole in the leg as at (6). Insert a blue coded cross rail through the elongated hole in the hinged member and into the hole in the leg and insert one of the hexagon head cap screws through the hole of the hinged member, the leg and into the rail. Now thread the two rails into the corresponding holes of the table leg having the blue coded instructions No. 2, Figure C, and insert the cap screws and draw them up securely. Now assemble the legs 1 and 1-A, having the red and white color coded instructions No. 7 and No. 8, Figure C, as outlined above.

It will be noticed that to each of the "red" and "white" legs are welded "V" shaped angles No. 9, Figure D, which serve as a pocket to store the radiographic tubestand when not in use.

After the two end legs have been assembled, as shown in Figure C, it is necessary to assemble the six long remaining pieces of tubing. The two with the section of rack must be joined together so that the teeth and rack are continuous. When assembling the rails, the color coded instructions must be at the outer extremities

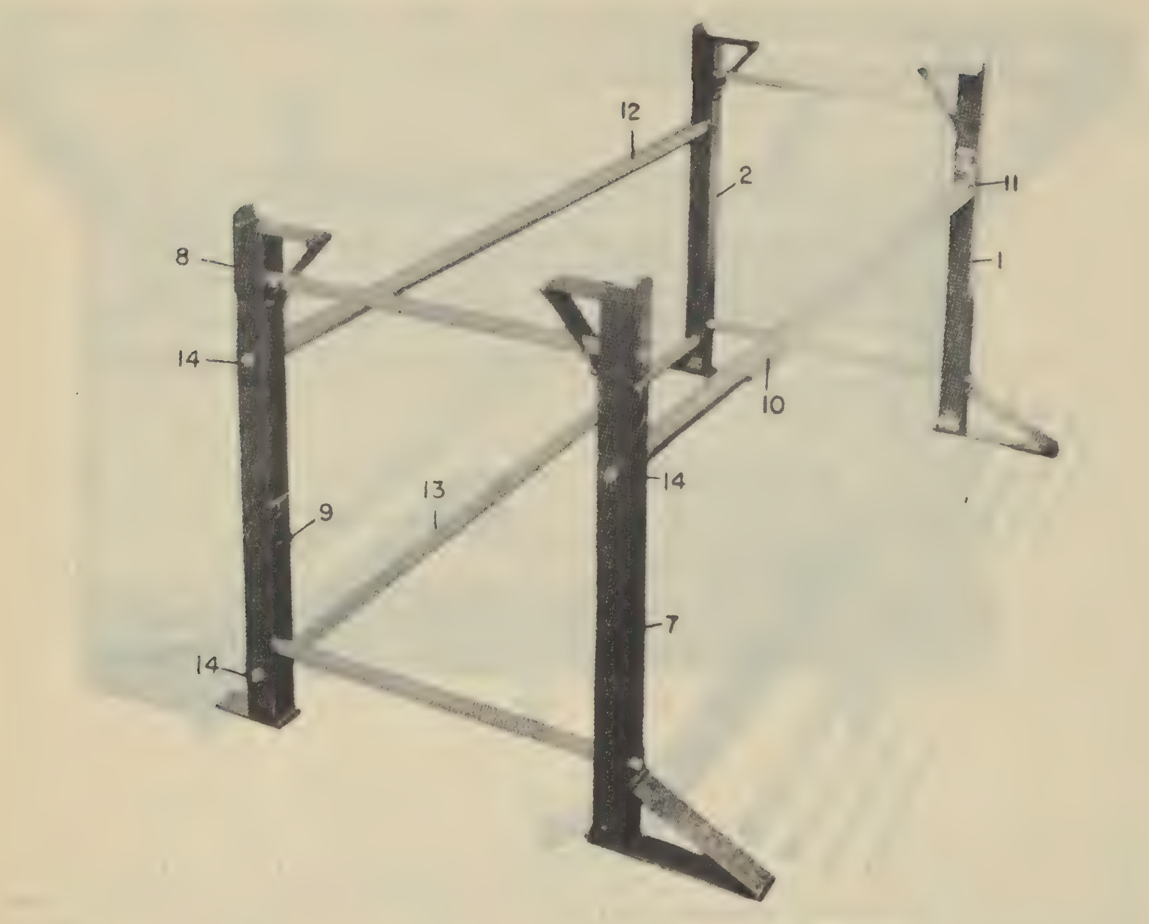


FIG. D

of the assembled rail. The remaining two of the same diameter should be not joined together. This then will leave two of similiar total length, but smaller diameter, that should be joined together. The section with the rack (10), Figure D, must be installed in the correct manner. The rack must point away from the table, and to be certain that it will, a notched member (11) is welded to the leg (yellow) No. 1 which must straddle the rack. Therefore, the color coded instructions on the rail (10) will match the corresponding color on the legs No. 1 and No. 7. The two remaining sections (12 and 13), Figure D, should be installed in the remaining holes in the legs No. 2 and No. 8 on the opposite side of the table. Now it is a good idea to assemble these tubular members to one end of the table first, if one has to work alone. If two men are available, all of this can be assembled at one time, The six long rods with a hexagon head at one end and a thread at the other end must be inserted through the legs as at (14), Figure D, into each end of these last named three longitudinal rails. It is best not to tighten any of the rods into their final positions until all have been inserted in place, and threads started evenly all around. Care should be exercised to pull them up tightly and yet not to overstrain them.

ASSEMBLY OF FLUOROSCOPIC MECHANISM - If the table framework has been unpacked and assembled in the proper manner, there should still remain in Chest No. 1 a tubular member (15), Figure B, with a section of gear rack extending about three-quarters of its length. One end of this assembly will be found to be open.

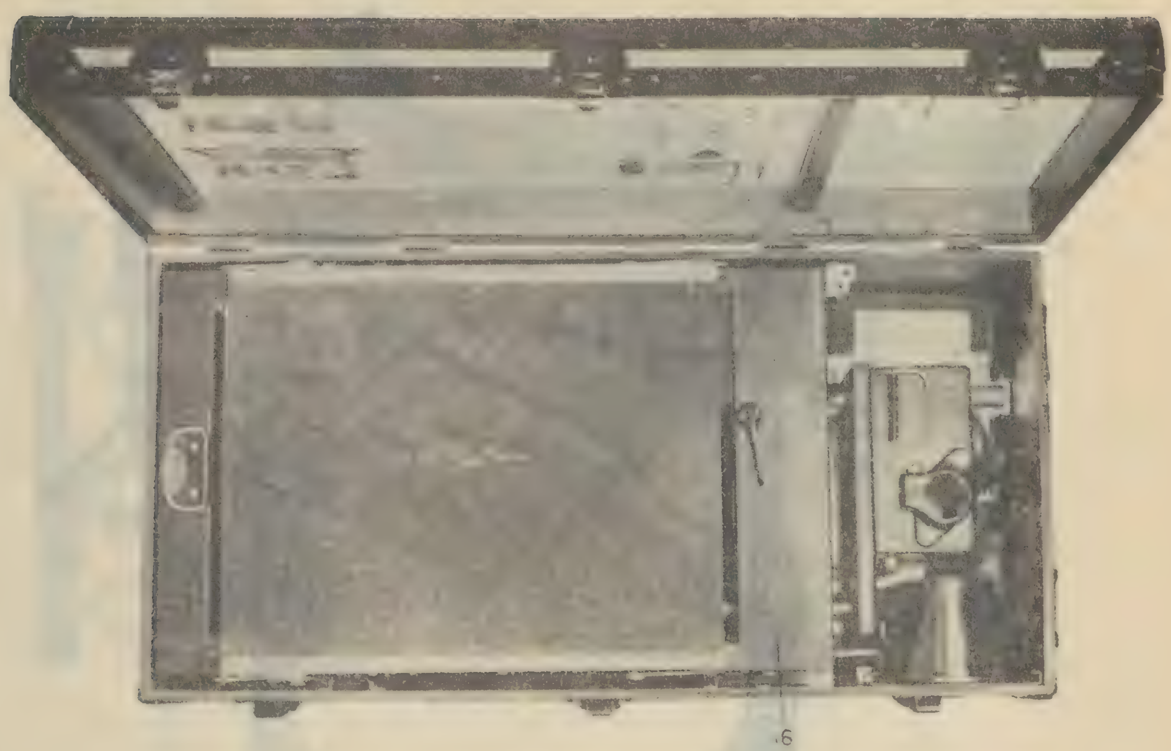


FIG. E

and the other end will have a means of mounting a supporting arm for the x-ray source. This is the vertical column. In the second chest (Chest No. 2) which belongs to the table, is packed the horizontal carriage assembly (16), Figure E. It will be noticed that there are four fittings which index with four packing brackets attached to the Chest No. 2. These fittings not only retain and support the carriage, but also reinforce the chest against side pressure. After this is removed, the vertical column with the rack must be installed. This must be done before the carriage is placed in the final position on the table. To do this, the vertical column is entered into the guide bushing from the underside, as indicated by the instructions printed on the gear housing of the cross travel section of the carriage, so that the open part of the tubing will point to the ceiling as shown in Figure F.

It will be noticed that there are two semicircular notches milled into the rack section of this tubular member. These are used as the upper and lower travel limit stops. In the inside of the gear box mechanism for raising and lowering the vertical column and tube head is a toggle stop mechanism which engages these milled slots when the lock lever No. 17, Figure F, is pointing towards the floor, thus providing a vertical travel stop for fluoroscopy. With the lever pointing to the ceiling, a stop is provided for radiography. Before inserting the vertical column in this gear housing, it will, therefore, be necessary to temporarily disengage this lock by turning it so that it points up or in the radiographic position, shown in Figure F.

In order to install the vertical column in the proper position, the crank (18), Figure F, must be removed from the tool compartment of the horizontal carriage

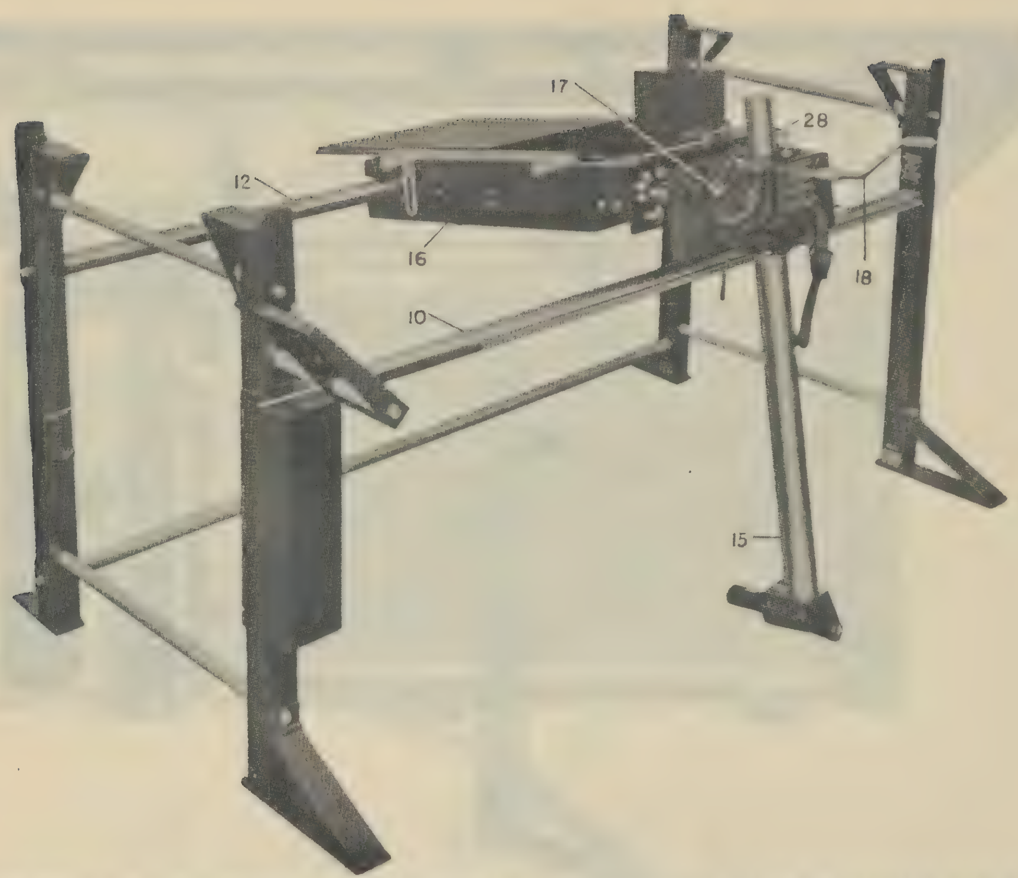


FIG. F

packed in Chest No. 2 and inserted into the carriage in order to turn the gears that will mesh with the rack. After this has been cranked sufficiently high so the lower end of the tubular member will clear the floor, the carriage can be installed on the table. This is done by engaging the bearings in the forked end of the horizontal carriage (16), Figure F, with the rail (12) first and then lowering the carriage until the rear bearings rest on the rail (10). The carriage should now be perfectly free to move from one end of the table to the other. It should be possible to unlock the cross travel carriage so as to move it crosswise of the table.

Returning now to the Chest No. 1, a member (19), Figure B, will be found with a large diameter bearing which will fit over the upper end of the tubular member (15), Figure G. This is the screen arm. If properly assembled, it should be possible by means of the lock (20) to secure this against rotation or to so free it that the arm can be turned from the center of the table.

In Chest No. 1 will be found a short tubular arm marked "tube arm" (21), Figure B, with a thumb screw near the center of its length and a disc near the other end. This can be slipped into the lower end of the vertical column (15), Figure G. It will be noted that there are two fittings at the lower extremity of the vertical column for the attachment of the Airflow shockproof head and Airflow tube. These fittings are so marked, and it is necessary to install the tube arm in the proper fitting in order to center the target with the center of the screen.

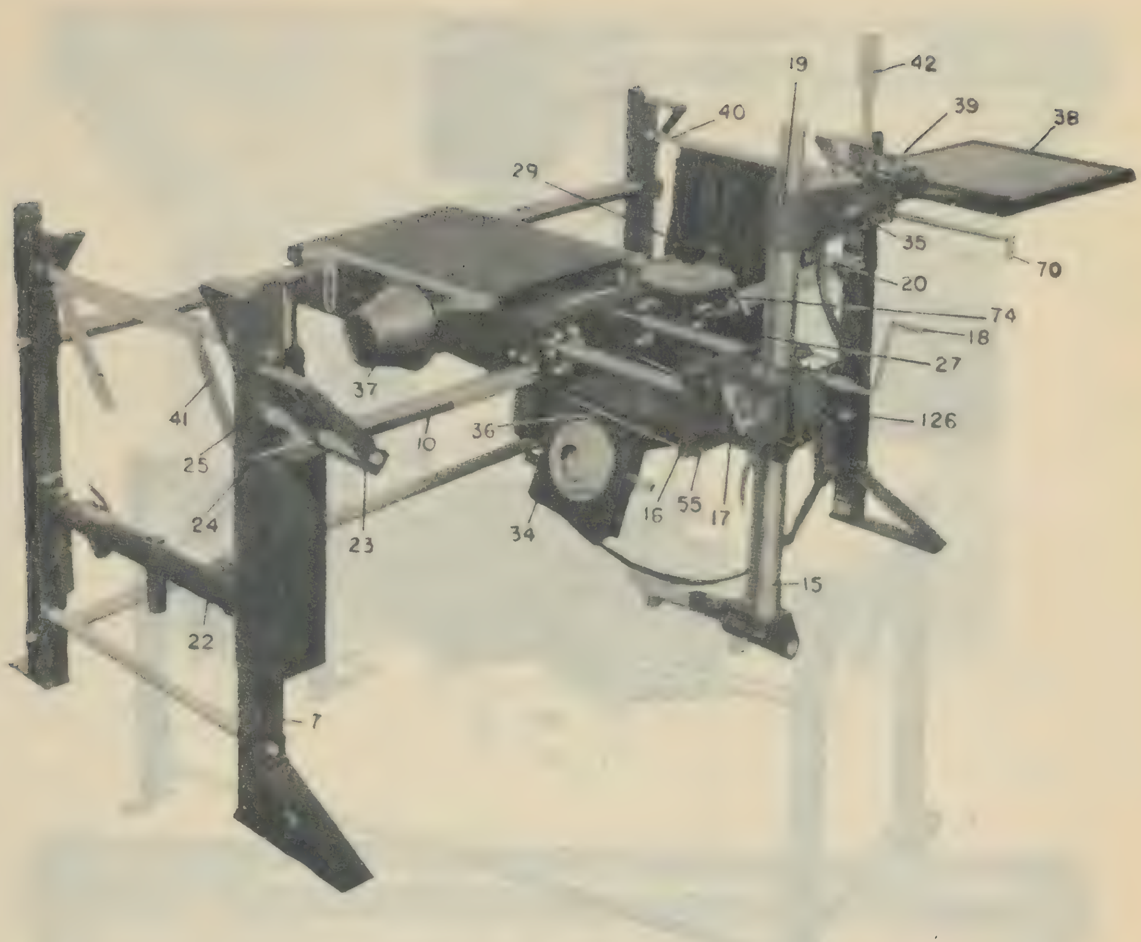


FIG. G

In Chest No. 1 in the compartment from which the vertical column (15), Figure B, was removed will be found a length of tubing to which is welded two short pieces of small diameter tubing, extending at right angles. This is the radiographic tubestand attachment (22), Figure G. This can be attached to the upper part of the adjustable vertical column with rack attached (15), Figure H. When so doing, it should be turned so that it indexes with the slots in member (15) in such a way that the extended tubing at the top points toward the center of the table. By use of the tube arm (21), Figure G, referred to earlier and which by this time should have been installed in the lower part of the vertical column, the tubestand can be made to support either the shockproof head of Item No. 96215 or the Airflow tube of the Standard Army Field Unit No. 96085 Generator, following the instructions for positioning attached to the tubestand.

It is necessary to observe that the tube arm (21) is indexed in the proper hole in the upper member of the tubestand (22). Otherwise, the focal spot will not travel equally either side of center of the table. It will be noted that the tubular fitting welded approximately 11 inches below the upper fitting has but one position for the tube arm, since for vertical radiography a patient can be shifted slightly to accommodate the difference in centering between the targets of the Airflow shockproof head or Airflow tube.

INSTALLING CONTROL

In Chest No. 1 will be found a rectangular sheet metal control shelf (23),

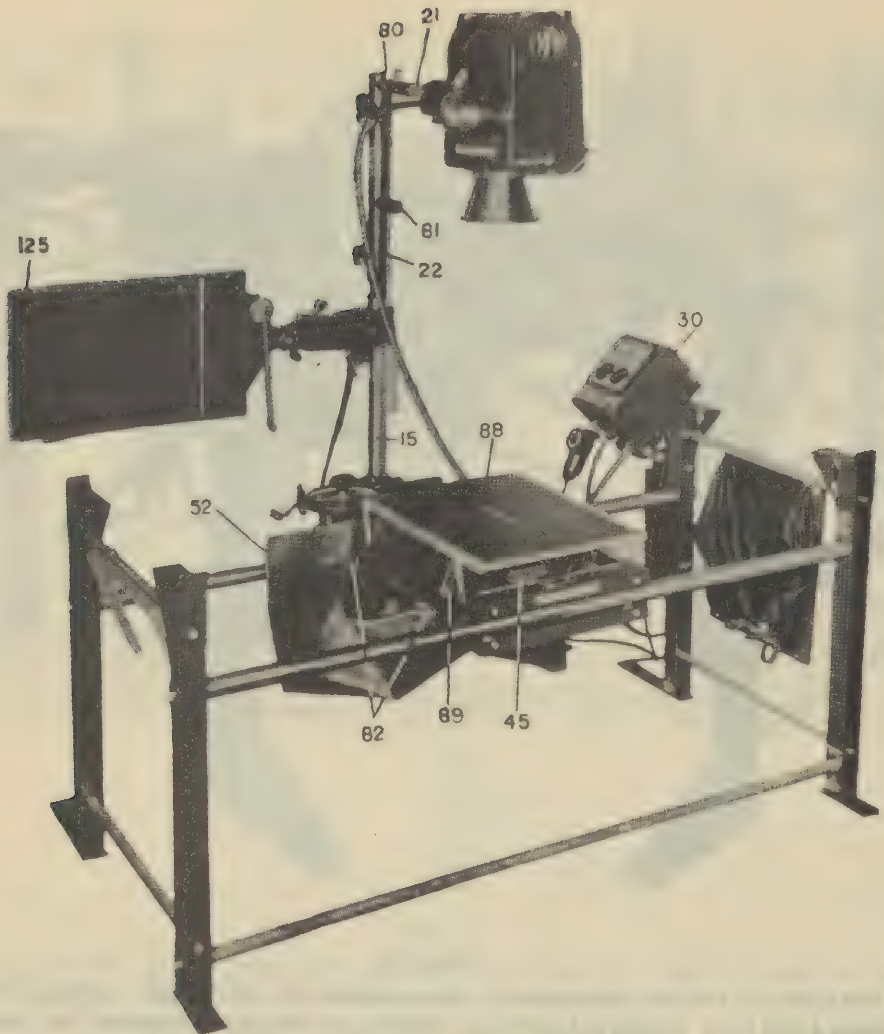


FIG. H

Figure G, to support the control (30), Figure H, together with a control support tube (24), Figure G, (with a threaded opening at each end) to which is attached an index pin (25). The "red" leg (7), Figure G, of the table, which should be at your extreme left if you stand at the side of the table on which is the rail (10) with rack attached, is equipped with a hole into which the control support tube will fit.

This control support tube (24) which protrudes through to the far side of the leg is attached to the leg by one of the hexagon head cap screws found in the tool compartment in the carriage. Before putting this in place, the spare x-ray tube container is removed from Chest No. 3, (31) Figure I, and this rod and indexing pin is passed through the holes provided in the spare x-ray tube container so as to support the spare tube against the leg of the table as shown in Figure G. If this is not done, the spare tube may not be readily available when it is needed.

The control shelf (23), Figure G, will then fit over the tubular member. Be sure that the notch in the one hole in the control shelf is positively engaged with the indexing pin in the control support tube before securing the shelf in place. Otherwise, when installing the control the shelf is apt to rotate, causing the

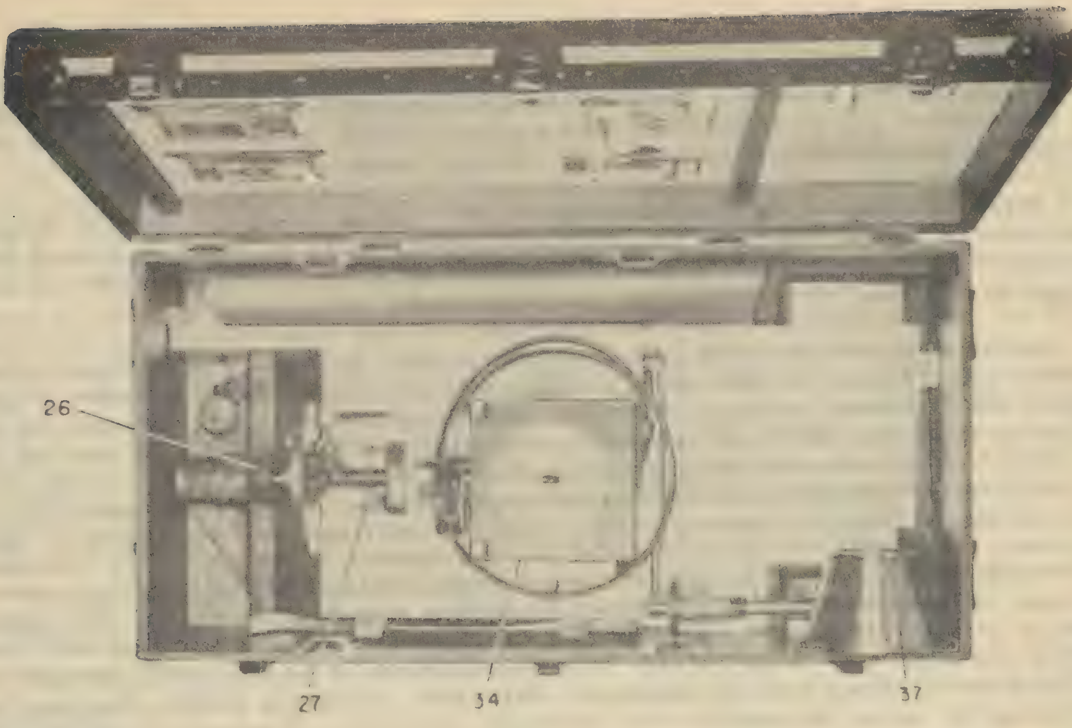


FIG. J

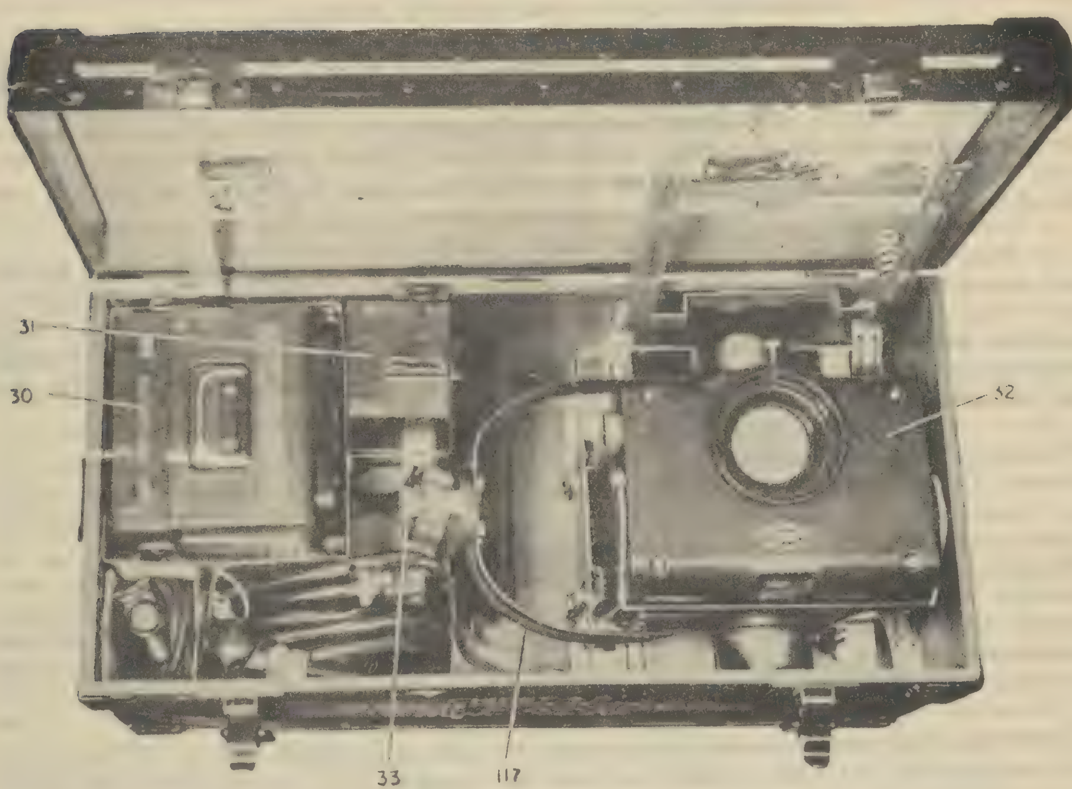


FIG. I

control to fall and possibly become damaged. This assembly will provide a supporting surface for the control. Beneath this shelf you will also find space provided for the complete set of filters and lead aperture plates, as well as a hook for the instruction booklet.

Three shoulder rivets will be noted on the top plane of the control shelf. These must be securely engaged into the three keyhole slots on the underside of the control. The control (30), Figure I, can now be removed from Chest No. 2 and secured in position.

INSTALLING LOCALIZER DIAL - In Chest No. 2 will be found the localizer dial assembly (26), Figure J. This should engage with the bracket and the tapped screw hole in the horizontal carriage. To remove the localizer dial from the chest it is necessary to loosen the thumb screw (77), Figure J, and then shift the housing to the left so that the two pins, found in line on the mounting bracket of the localizer dial, disengage from the fitting in the chest. It will be noted that a corresponding fitting is fastened to the horizontal carriage at (28), Figure F, and, therefore, to install the localizer dial it is necessary to re-engage the two pins in the dial with the holes in this fitting and then swing the localizer dial clocks wise and tighten the thumb screw (27). The spring incorporated within this thumb screw is arranged to keep the gear of the localizer dial in constant mesh with the rack on the rail. In doing foreign body localization it is of utmost importance that the screen should not be touched. This will introduce errors that can be eliminated by using the knob on the localizer dial (29), Figure G, to drive the carriage and screen assembly. The longitudinal travel of the carriage can be arrested by means of the lock (74), Figure G.

OPERATOR'S X-RAY PROTECTIVE SHIELD

In Chest No. 1 there is packed an x-ray opaque apron or shield intended for attachment to the carriage system of the table. It is highly important that this be installed, and installed correctly, in order to give the operator as much protection as is practical. It is also important that the operator fully realizes the importance of wearing the lead rubber apron and lead rubber gloves packed with the goggles in Chest No. 2. The protective shield is only intended to protect the operator's lower extremities.

In Chest No. 1 there is provision for packing an extra lead rubber apron, gloves, and fluoroscopic goggles in the covered compartment used for the protective shield. The apron should be rolled or folded so as to occupy a space about four inches wide by the width of the apron. The end of the apron then protrudes through the opening in the covered compartment in Chest No. 1 and allows enough room for the carton containing the gloves and the one containing the goggles.

The x-ray protective shield, (48), Figure A, is equipped with fittings for its attachment to the horizontal carriage. Along one end of the shield will be found sewn a formed wire rod and this end is to be attached to the horizontal carriage on the localizer dial side as shown in Figure A. This shield is so designed that it can be used with the Airflow head of Item No. 96215, of the Airflow tube of the Army Field Unit Item No. 96085. When properly installed this provides a considerable degree of protection from the scattered radiation coming back from the patient and the underside of the diaphragm. Thus it protects the lower parts of the leg and feet of the operator from this secondary radiation.

To attach the protective shield, which is packed in Chest No. 1, it is necessary to engage the rod (52), Figure A, into the bracket (53) attached to the innerside of the horizontal carriage on the operator's side of the table. The short end

of the rod which is bent at right angles enters into a hole at (54) in the top of the horizontal carriage just behind the localizer dial.

All these points of attachment are clearly indicated with instructions attached to the various parts of the table. Now the straps sewn along the edges of the protective shield must be attached. The one along the right forward edge (from the operator's position) should be attached to the support leg of the Airflow head as shown at (49), Figure A. The strap can be inserted within the leg and drawn up as far as it will go. Stops are provided on the strap to prevent it from being so secured as to restrict cross travel. The two straps sewn along the edge of the left side of the shield should be similarly attached to the tube arm and the yoke as shown at (50) and (51) respectively, Figure K. Care should be observed when attaching the shield that it in no way restricts the flow of air into the blower system. If the table is to be used for radiography, the shield can be stored with the unit by leaving the rod (52) attached and then suspending the opposite end of the shield by means of the eyes fastening the straps to it to the fitting (82) as shown in Figure N.

During the past few years manufacturers of x-ray apparatus have been constantly striving to make their equipment as stray-radiation-proof as possible.

The x-ray protective shield furnished with this unit is an additional effort to meet present-day standards, although from time to time further improvements may be made.

If you should receive, on request, a replacement x-ray protective shield because of deterioration of or damage to the shield, one which is entirely different in design than the one you have been using, please insert the instructions which will be supplied with the new shield in the place of the data in this manual referring to the shield.

INSTALLING BRACE RODS

The brace rods (36), Figure G, can now be installed on the moving carriage system. This should be done before the Airflow tube head is in place. In the elevating mechanism housing, in which the crank is installed for raising and lowering the tube, will be noted two holes. They are away from the operator, down as low as possible in a flange as at (55), Figure G. One end of each brace rod should be hooked in these holes. The other end of the brace rods should be engaged in the holes provided for them in the inner support plate (45), Figure H, providing the rods are extended as far as possible. Always keep the eccentric levers toward the vertical column side of the horizontal carriage in order to prevent interference with the diaphragm housing. If the eccentric levers are snapped up into position, these rods will tend to greatly stiffen the whole assembly. If there is not good eccentric snap action, putting these rods into place, the rods can be adjusted until there is a definite snap action.

INSTALLING SHOCKPROOF HEAD

From Chest No. 3 the shockproof head (32) can be removed after the strap holding the yoke (117), Figure I, has been undone. Be sure to fasten this strap about the yoke when repacking, and it can either be installed over or under the table, depending upon the work to be done. If it is to be installed under the table, it must be installed in the correct one of the two openings provided. It will be noted that one of these openings is to support the Airflow shockproof tube of the standard Army Field Unit, and is so marked, while the second opening is to support the Airflow shockproof head.

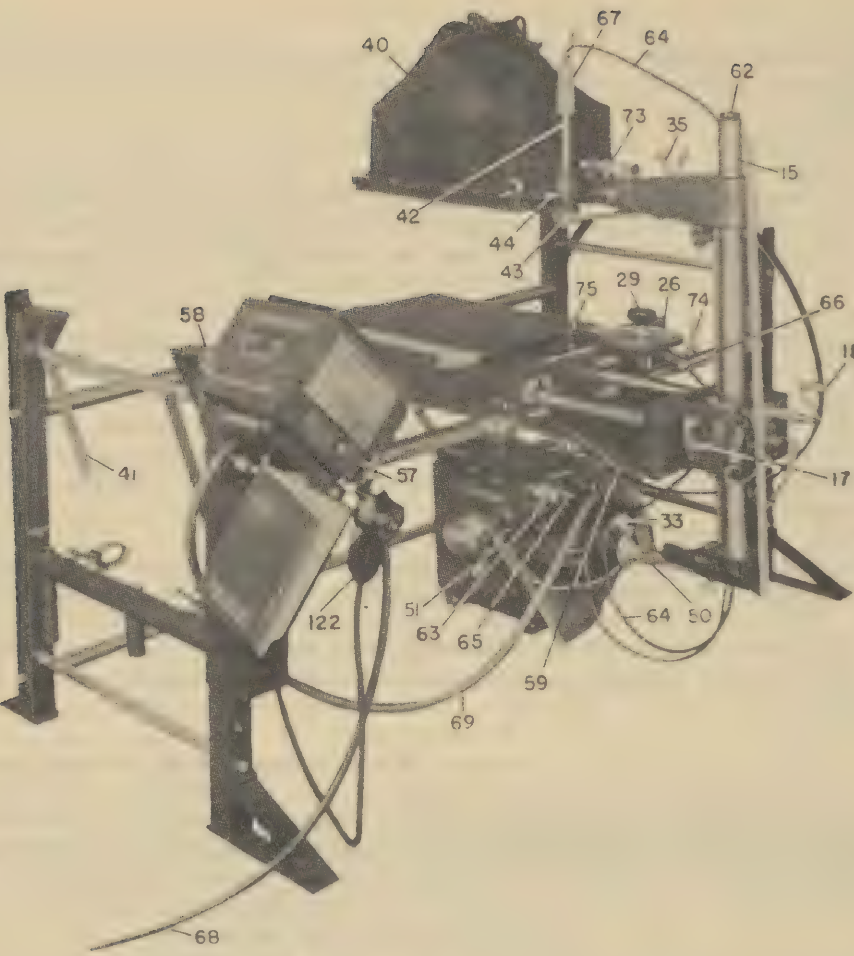


FIG. K

If the shockproof head is placed under the table with the hanger parallel to the floor and pointing towards the operator's side of the table, the vertical column and the tube arm can be cranked up or down to the proper level and the carriage of the table moved in or out so as to engage the hanger of the shockproof head without the necessity of lifting it manually. In order to install the shockproof head it will be necessary to loosen the thumb screw (33), Figure K, of the retaining bracket, so that when the tube arm is inserted into the hanger and the thumb screw tightened, the retaining bracket will engage with the beveled edge of the disc on the tube arm. After the retaining bracket has been properly engaged, the entire head and support can be cranked to the desired level. After raising it about four inches from the floor, turn the vertical travel limit stop (17) to the correct position as shown in Figure K.

INSTALLING DIAPHRAGM ASSEMBLY

Assuming that the head has been installed under the table, you can now remove the diaphragm (34), Figure J, with extension control from Chest No. 2. Install this on the shockproof head or x-ray tube which should have the ray aperture pointing upward. After this end is secured, the diaphragm control lever assembly should be secured to the side of the screen supporting arm at (35), Figure G. The shutter control cable should be installed behind the hook (126) in order to minimize

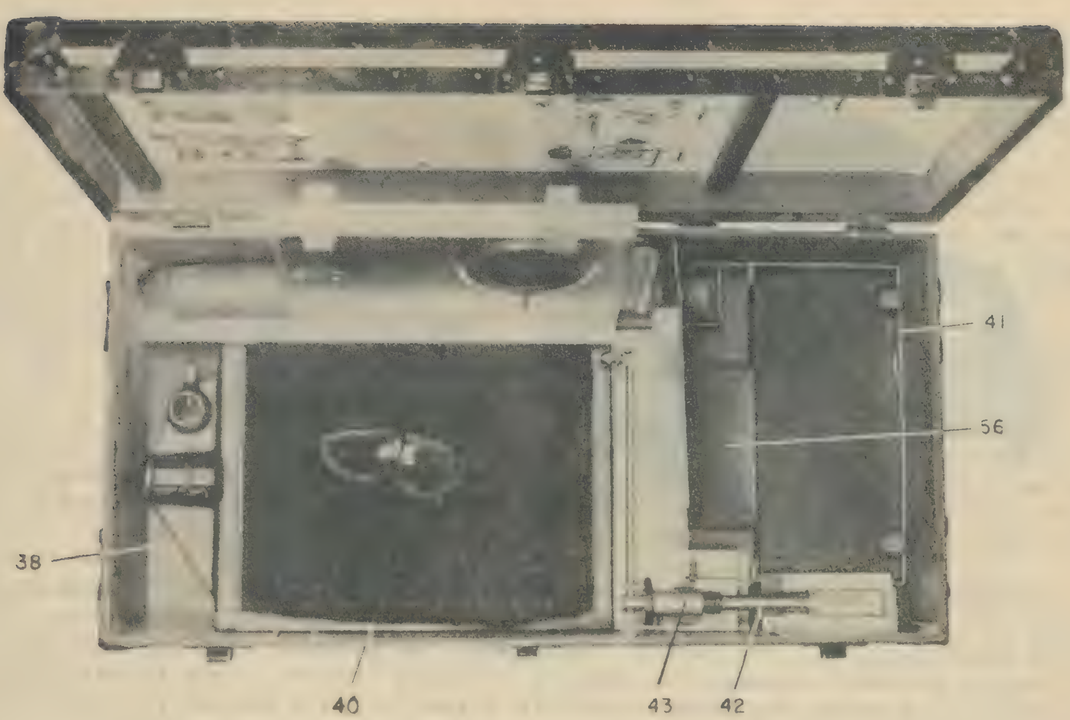


FIG. L

interference with the crank. It will be noted that there are two hooks provided on the underside of the diaphragm housing. These are arranged so that if it would be desirable to remove the x-ray tube from the fluoroscopic position for radiography, the diaphragm housing can be stored by hanging it on the brace rod (36), Figure G. The cone (37), Figure J, can now be removed from Chest No. 2 and installed in the top of the diaphragm (34). Two slides will be found welded to the horizontal carriage for the storage of the cone when not in use, as shown in Figure G.

ATTACHING VIBRATION DAMPENER - Attached to the inner support plate (45), Figure H, is a vibration dampener (46), Figure A, with instructions for its attachment. This consists of two pieces of steel about six inches long, joined together in a pivoted manner, with friction washers at the pivot and with a thumb screw (47) at one end. Now looking at the table on the side away from the localizing dial, it will be noted that the edge of the cover of the Airflow head has a fitting with a tapped hole to receive the wing screw of the vibration dampener. When properly assembled, this provides a hinged action which tends to stabilize and dampen out vibration of the shockproof head.

INSTALLING SCREEN ASSEMBLY - From Chest No. 2 remove the screen assembly (38), Figure L, with daylight fluoroscopic hood (40) attached. A bearing on the end of this can be attached directly to the shaft extending from the screen assembly support arm (19), Figure G. This should be secured with the thumb screw (39), indicated by the instructions attached to the screen.

PACKING SCREEN - Be sure when repacking the screen that the grid and fluoroscopic hood, with the retainers collapsed, are installed. Insert the screen

assembly between the rubber bumpers attached to the wall of the compartment having the hinges for its cover. The opposite side of the screen should then rest on the bumpers attached to the front wall of the chest and will be retained by the bumpers in the lid.

It will be noted that the screen assembly includes a fluoroscopic grid which can be removed and a daylight fluoroscopic hood (40) which can also be removed. Hooks are provided on the hood assembly so that it can be hung on one of the cross members at the end of the table so as to provide a convenient place to store it when not in use, as shown in Figure G. The fluoroscopic grid is of the focused type and it is necessary when using it for either fluoroscopy or radiography that the proper side faces the x-ray source. Otherwise, cutoff will result. The grid is marked. Be sure to use it as instructed.

In Chest No. 2 will be found a "U" shaped member (41), Figure L, with four studs attached and including a pair of hooks. This is a gauge to be used in checking and adjusting the localizer mechanism so as to maintain maximum accuracy. The hooks make it possible to hang this member on the top cross rail at the end of the table when it is not in use as shown in Figure G.

INSTALLING DEPTH CAUGE - In Chest No. 2 you will find an "L" shaped assembly (42), Figure L, with a graduated lucite rod in a steel tubular member. This is the depth gauge and skin marker. This should be inserted from the underside of the screen assembly through the opening provided for it. This is retained in position by tightening the thumb screw (44), Figure L, after the pin projecting from the bearing (43) has engaged the hole provided for it in the screen frame.

DAYLIGHT FLUOROSCOPIC HOOD

To avoid the necessity of using a dark room during fluoroscopy, a cloth hood (40), Figure L, is provided mounted on the metal frame arranged to make a light-tight fit to the fluoroscopic screen frame. This can be readily aligned over the fluoroscopic screen until the entire area is covered and the indexing pin engages with the hole in the end of the fluoroscopic screen frame. It is readily removable. hoods are provided so that it can be hung at the end of the table when not in use. The small end of the hood terminates in a pair of special goggles. These are designed so that they may be worn over prescription eye glasses and are ventilated in a manner as to prevent the entrance of light. The edges are lined with sponge rubber to conform to the shape of the face and to exclude light. After a little practice, it will be found entirely practical to do fluoroscopic work with this attachment without the use of a dark room. Fluoroscopic goggles are recommended to retain eye accommodation. To prevent the fluoroscopic hood from collapsing or restricting the field of vision, a metal framework is pivoted to the frame to which the cloth is attached. In order to erect the framework of the hood, it is necessary to grasp through the hood, and with the fingers locate the metal frames and turn them upward. Springs will then retain the frames. There are two of them. After they are put in the proper position it will be found that the cloth hood will not unduly lie over the fluoroscopic screen. A pair of fluoroscopic goggles are included in Chest No. 2. It is recommended that when removing the goggles attached to the daylight hood that the eyes momentarily be closed and that the fluoroscopic goggles (86), Figure L, be put in place, thus not exposing the eyes to too much strong light between examinations.

CONTROL UNIT

The control unit though small and light in weight, has many of the features of much larger and heavier units, and in addition has some that they do not have, such as automatic selection of the proper [illegible] to the milliamperes as

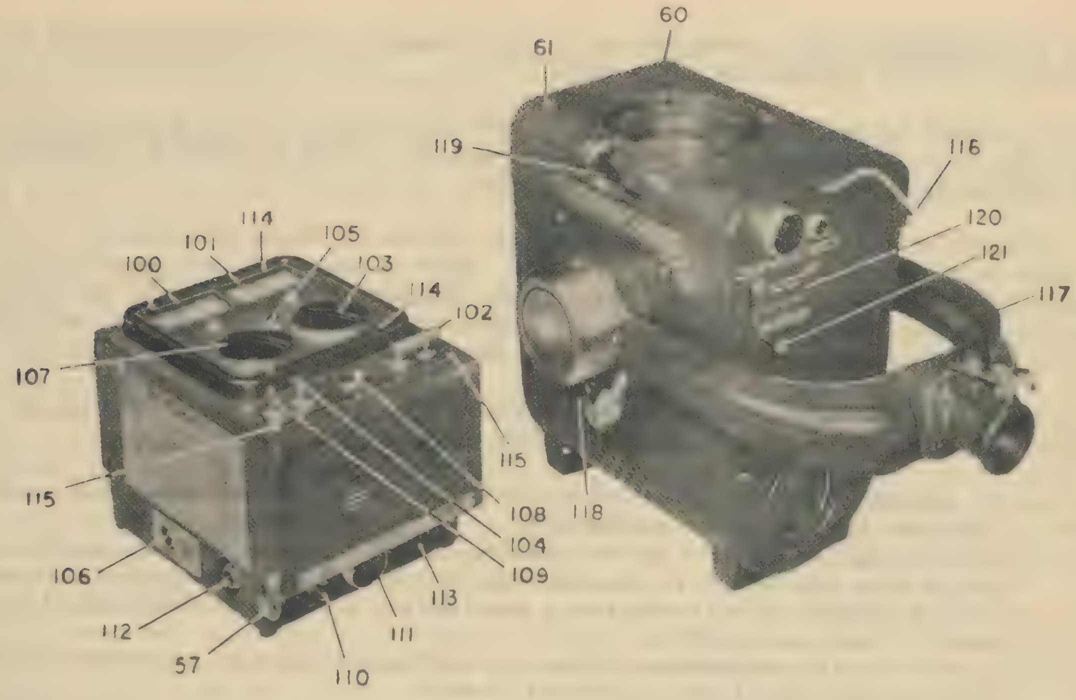


FIG. M

that the control may be plugged in any line of 50 to 60 cycles with nominal voltage of either 110 or 220. The rating of the control is 15 M.A. maximum and 80 P.Kv. maximum. For more detail ratings see the large name plate on the side on the control case.

In order to facilitate the description of the control and to describe its various functions, each of the component parts will be considered separately.

KILOVOLT METER "D" - Scale "D" of the voltmeter (100), Figure M, shows the kilovoltage applied to the x-ray tube under load. It should be emphasized in connection with this kilovoltage scale that the meter indicates the kilovoltage applied to the x-ray tube with current passing through the tube, and if a pre-setting of this meter is desired, it will be necessary to determine what drop in meter reading is developed for each setting of milliamperage used. It is not possible to pre-calibrate this instrument because it may be operated on different types of service, each of which will require individual calibration.

It will be noted that the voltmeter calibrations utilize an expanded scale so that the lowest kilovoltage reading appears very close to the zero point, and in this manner utilizes the entire meter scale rather than the conventional simple voltmeter which would only allow the use of about 60% of the scale. This expanded scale feature is accomplished in the calibration of the voltmeter for both the 5 and 15 M.A. technique by supplying the proper amount of reversed voltage from a separate isolated winding on the autotransformer. The switching from the 5 M.A. to the 15 M.A. calibration is accomplished by radiographic fluoroscopic safety switch (102), Figure M.

MILLIAMMETER "J" - Scale "J" of the milliammeter (101) indicates the milliamperage passing through the x-ray tube.

It should be noted that part of the scale is printed in red, indicating that operation is in the danger zone and the milliamperage should be lowered by adjusting the milliamperage control (103) counterclockwise.

Special attention has been devoted to the design of these instruments to give maximum service under extreme conditions. Both instruments are provided with shatterproof glass windows and with a second translucent plastic cover to prevent possible damage or breakage. Also, both instruments are suspended on air foam rubber in all directions to prevent possible damage to the movements by vibration.

RADIOGRAPHIC FLUOROSCOPIC SAFETY SWITCH "B" - This switch is a four pole, double throw toggle switch and serves the following functions:

1. It changes the calibration of the voltmeter as described above when changing from fluoroscopy to radiography.
2. It changes the control of the main contactor from the push button to the timer when the switch is changed from fluoroscopy to radiography. A footswitch may be substituted for a push button since the identical plug is used on both accessories.
3. It changes the calibration of the circuit breaker from an approximate tripping value of 7 M.A. to a value of 18 M.A.
4. It changes the illumination of the meters from dim to bright when switching from fluoroscopy to radiography.

MAIN CONTACTOR - Although the control is small, it includes a relay or contactor to open and close the circuit to the primary of the high tension transformer. By means of its auxiliary contacts, it also controls the intermittent illumination of the skin depth gauge and the localizer dial. These lights are "ON" when the fluoroscopic exposure is "OFF". This contactor is, of course, controlled by the timer, push button or footswitch.

CIRCUIT BREAKER AND "BREAKER RESET", "H" - A special circuit breaker was developed for this equipment. It is much smaller, lighter, and faster in its operation than conventional circuit breakers. It is actuated by overloads in the secondary circuit of the high tension transformer instead of overloads in the primary circuit as is the usual practice. It requires a small lock-out relay to keep the circuit breaker relay in an open position after an overload occurs. The lock-out relay also extinguishes the pilot light (105), indicating that the circuit breaker must be reset by means of the "Breaker Reset" switch (104), Figure M, on the board. The circuit breaker relay has the equivalent of two coils, one in each side of the ground mid secondary circuit so that an overload occurring on either side on the high tension transformer causes the circuit breaker to instantly open, thereby de-energizing the main contactor which simultaneously opens the primary circuit of the high tension transformer.

AUTOMATIC 115 OR 230 VOLT OPERATION - At times 115 volts may not be available for the operation of this equipment. It has, therefore, been designed so that it can be operated on circuits of 115 or 230 volts. As a matter of fact, the range is even greater. It can be operated on lines from 100 to 130 volts, and from 200 to 240 volts. On a machine which has this range, it is obviously possible that it may be connected internally for operation on a 115-volt circuit, and it might thoughtlessly be connected to a 230-volt circuit. This naturally would burn out the unit. To prevent this possibility, an automatic changeover is incorporated within the

control which adapts the internal circuits to either voltage depending upon the supply to which the unit is connected.

This is accomplished by a special relay. If it is connected to a 115 volt line, the relay will remain in the 115-volt or open position. If it is connected to a 230-volt line, the relay will close and transfer to the 230 volt winding of the autotransformer.

LINE COMPENSATOR - If the line is not exactly 115 or exactly 230 volts, the range of the filament control will be affected and the calibration of the device will not be accurate. To compensate for higher or lower lines, a selector switch (106) is provided on the side of the control which can be adjusted by a coin until the pointer coincides with the red line of the kilovoltmeter. This adjustment, however, must be made when certain other controls on the switchboard are in the correct position. To simplify this, these controls have red dots to indicate the proper positions to which the knobs or pointers should be turned. It is, therefore, necessary to turn the minor kilovoltage selector (107) to the red dot next to button No. 3 Figure M, and set the radiographic fluoroscopic switch (102) to the red dot or "radiography" side and set the main switch (108) to the red dot or "High" side. When all of these controls have been properly set, the adjuster on the side of the control should be manipulated so that the pointer of the kilovoltmeter is made to coincide with the red line on the scale and the unit is then ready for operation. It must, of course, be understood that this equipment must be operated on alternating current. Direct current will burn it out. It must also be operated on circuits whose frequency lies within the range of the design, from 50 to 60 cycles.

Warning: Never plug into a line without being certain that the main switch is in the Central or "OFF" position.

AUTOTRANSFORMER - The autotransformer is provided with the necessary taps to permit a wide range of kilovoltage selection. The top of the control includes an 11 point control knob (107) labeled "C". This provides for 11 small steps of kilovoltage adjustment. The main switch (108) labeled "A" is capable of adjustment into three positions: Off, Low and High. In the high position, the maximum kilovoltage is slightly above 80. However, the unit must not be operated with the kilovoltmeter reading higher than 80 Kv. under load. With the main switch in the low position, the lowest kilovoltage available is approximately 40 Kv. Thus, these switch combinations provide a range from 40 Kv. to 80 Kv. in approximately 2 kilovolt steps.

FILAMENT CONTROL "G" - A filament control (103) is provided so that the milliamperage may be adjusted to any value up to 15 M.A. To conserve weight and space, a rheostat is utilized for this purpose with a specially tapered winding for proper regulation. It will be found that the adjustment is spread over approximately 250° of rotation of the control knob, thus providing a fine degree of regulation of milliamperage. Now if the filament control is turned too high, so that more than 7 M.A. passes through the x-ray tube, an overload will occur and the circuit breaker will kick out. Thus the circuit breaker is made to protect against overloads during fluoroscopy. Under no conditions should the unit be operated fluoroscopically over 5 M.A. If the operator's eyes are properly accommodated, it will generally be found possible to operate with lower than 5 M.A. Thus the radiation that the patient or the operator will receive will be reduced and the life of the x-ray tube will be prolonged.

"CHECK FILAMENT" SWITCH, "E" - With this switch (109) in its normal position, the kilovoltmeter scale indicates load kilovolts as applied to the x-ray

tube. When this switch is depressed and held to the preset filament position, the upper scale "F" of the kilovoltmeter indicates relatively the current passing through the filament of the x-ray tube. Therefore, if the operator will tabulate the settings on this scale which correspond, for example, to 5, 10, and 15 M.A., it will always be possible to preset to these milliamperages without exciting the x-ray tube, and again prolong tube life.

RECEPTACLES - All incoming and outgoing circuits terminate in a variety of receptacles. Each is made different so as to eliminate the possibility of mis-connection. Those which require it are polarized so that the plug can only enter the receptacle one way. The receptacles are in protected positions. They include the following:

a. A receptacle (110) for the incoming main line and ground connection.
b. A receptacle (111) for the connection of either a push button or a foot-switch.
c. A receptacle for the hand timer on the right side of the control.
d. A receptacle (112) for the localizer illumination which provides current for both the dial of the localizer and the screen skin distance gauge.
e. A receptacle (113) for all of the circuits to the shockproof head. This not only includes the circuits necessary for the operation of the transformer, but it further includes the connections for the internal oil circulator and blower built within the shockproof head, and the circuits for an automatic thermal shut off which will stop the exposure if the tube head overheats. Further, it includes duplicate circuits for the localizer lights and the push button so that it is not necessary to carry extra cords from the moving carriage system of the table back to the control.

CONTROL FEATURES IN GENERAL - It will be noted that hooks (57), Figure K, are provided on the sides of the control on which a timer can be hung or cords may be placed. A cover (58) is provided at the lower rear of the control which, when removed, will expose a kit of spare parts and a few tools which should be sufficient to handle ordinary service which may be required. On the front of the control is a removable "Dot" plug which permits adjustment of the circuit breaker relay without removing the entire control case.

Various instructions will be observed on the plates attached to the control. *It is important that all of them be carefully followed. It will be noted that the meter scales, the various knobs and switches are marked alphabetically. If the machine is always operated in alphabetical sequence, it will simplify the operation considerably and it is an ideal way for an inexperienced operator to learn the proper operation of the equipment.*

CONTROL ACCESSIBILITY - If it becomes necessary to remove a meter or a pilot light, this can be accomplished by removing the four screws (114) from the frame around the top name plate. Next remove the two large knobs, (103) and (107), from their recesses by pulling straight off. Directly under these knobs will be found a nut, the removal of which will make it possible to lift up the entire name plate assembly. This will expose the central pilot light (105) and will further make it possible to lift the meters and expose the connections at the rear. The illumination for the meters is accomplished by means of a socket and lamp at the rear of the meter. These can easily be withdrawn for replacement. Spare bulbs will be found in the repair kit.

If it should become necessary to remove a case from the control, a series of eight screws will be noted along the lower edge of the main upper case. Some extend

through the hooks. These should be removed. The frame and plate referred to in the preceeding paragraph should also be removed. The tie bar across the fluoroscopic-radiographic switch (102) should be slipped off. The round knurled finishing nuts over the switches (102, 104, and 109) must be removed. The two screws (115) along the front edge of the control through the switch nameplate should be removed. It should then be possible to jar or work the case up off the base section of the control. In reassembling, it is important to be sure that all of these operations are handled in the reverse order and that the meters are properly seated on their sponge rubber mountings.

When the cover is removed from the control, it will appear to be quite inaccessible due to its compact form. After much development, it has been possible to arrange this so that it is much more accessible than it appears. If it should be found necessary to dismantle this unit further, it will first be necessary to remove the two screws extending through the timer receptacle plate on the right side of the control, and two screws through the line adjuster plate (106) on the opposite side of the control. Four screws will be noted on the underside of the control. They secure the autotransformer to the base. They must be removed. Two screws will be observed in line with the center of the front receptacle panel passing through the chassis member proper. There must be removed. See Figure Y:

After these various screws have been taken from their places, the entire chassis of the unit can be lifted up from the base. This operation will greatly increase the accessibility, but if necessary the unit can be broken down further.

The entire relay assembly is mounted on a panel which can be detached mechanically and electrically from the rest of the assembly. Just behind this panel board on the right and the left will be noted multiple plug-in jacks. These can very carefully be pried apart by a screw driver. It must be done evenly and with great care or the bakelite mounting straps will be broken. By taking this apart and removing the two screws holding this relay panel to the top subpanel, the entire relay-assembly can be laid to one side, making it very much easier to get at the rest of the mechanism. If by chance it is desired to break the unit down still further, another multiple plug and jack assembly will be noticed which when disconnected will permit removing the autotransformer assembly from the balance of the electrical parts.

A wiring diagram is provided on one inside face on the control case and on the inside of the lid of the spare parts box. Near the back of this booklet will be found a larger wiring diagram and also isolated circuit diagrams showing in detail each part of the circuit.

SHOCKPROOF HEAD

The shockproof head unit embodies essentially, a specially fabricated steel tank containing the high-voltage transformer, filament transformer, the x-ray tube, the impeller motor, the expansion chambers and the thermal overload switch. These units are immersed in specially dehydrated mineral oil after being heat treated to exclude possible moisture inclusion. This unit is then sealed off to the outside atmosphere after being vacuum treated for a prolonged period. The seal is made by means of a cover and proper sealing gasket. This cover incorporates a special x-ray translucent window as well as the connecting studs for the proper electrical connection of the internal component parts.

A port (120) is provided on the end of the tank to permit removal and entry of replacement x-ray tubes so as to permit simple tube replacement without dismantling the complete head. Since the unit is entirely sealed off to the atmosphere, it is obviously possible to operate and rotate the shockproof head in any direction.

However, care should be exercised in handling the unit so that it does not receive such rough usage as to dent any part of the tank unit or the outer enclosure. Reasonable factors of safety have been considered to anticipate unusual strain conditions. However, every attempt has also been made to reduce the weight to an absolute minimum and the unit must be handled with reasonable care.

This shockproof head has been designed to operate only in conjunction with the control unit described herein, and should not be operated under any other condition.

A special note should be made at this point that the oil used in this head is specially dehydrated oil similar to clear, dry medicinal oil used by the Medical Division of the U.S. Army, and if it should become necessary at some future date to add oil to the unit when, for instance, replacing an x-ray tube, only this type of oil should be used or a breakdown of the insulation may result.

Input studs are provided for the excitation of the high-tension primary filament transformer and the impeller motor, and in addition two leads are provided for the milliammeter and connection is provided for thermal safety switch and a ground stud. The other stud for the thermal switch is common with one of the impeller motor studs. Special oil impervious insulated leads are provided for connection from these studs to the multiple receptacle. In case of emergency where either this receptacle or its companion plug was damaged it is possible to connect the leads from the cable directly to the stud on this transformer top.

This completely sealed unit is next enclosed in a second casing which also contains a quadruple wheel blower. This second casing is so designed as to leave space between the inner tank and the outer casing, forming a duct for the passage of air over the completely sealed unit when the final cover is attached.

The air duct system of the unit is designed so as to pass air over as much of the surface of the inner tank as possible. The air passes into the two outer turbine blower wheels by way of the grilled end openings and the center wheels by way of the perforated center section of the housing. The air is driven from the wheels, around the tank, over the top, and out through the side perforations in the outer casing.

The x-ray tube and transformers of this unit represent adaptation of field tested units representing many years of service, and the test units have been operated on consecutive cycles, running for long periods of time.

One of the many features contributing to the successful operation of this unit is the patented motor-driven impeller which constantly circulates a stream of oil over the anode stem of the x-ray tube, which ultimately transfers the heat of the anode to the transformer tank casing. The air blower and duct system conducts the heat from this tank very rapidly.

The x-ray tube has a special high dielectric moulded cradle mounting which permits rapid changing of the tubes in the field. It has a 1.5 mm. focal spot and is self-protected by its metallic lead sheath which is mounted onto the x-ray tube itself and insulated by means of a mica barrier. The high-tension transformer of the unit has a high dielectric insulating shelf which provides the necessary seat and indices for receiving the cradle of the x-ray tube. The x-ray beam leaves the shockproof head through a recessed port which is made of special plastic which will not deteriorate rapidly in the presence of x-rays. The port is recessed so that a minimum amount of oil is interposed between the glass of the x-ray tube and the port window and reduces inherent filtration of the unit to a minimum.

As the temperature of the oil increases, its volume necessarily increases in a proportionate manner and since the unit is sealed off to the atmosphere, metallic bellows are incorporated in each side of the tank which compensates for the extremes of volumetric changes of the oil. As a safety measure, a specially designed switch and visible signal button has been incorporated in the one bellows so that as the bellows expansion reaches its limit the button starts to project and exposes a red section of its length, indicating to the operator that the unit is approaching its total heat capacity. If operation is continued beyond this point and more heat is generated than the unit will safely allow, the safety switch incorporated trips and opens the main contactor circuit. It will remain open until the unit has cooled down to the point of again allowing a definite operating period. The differential of time between opening and resetting of the switch is governed by the overcenter mechanical action of the switch incorporated. For instance, if a fluoroscopic milliamperage of five is exceeded or if the five milliamperage technic is operated for too long a period, the gradual heating of the oil will cause the expansion chamber to move outward and the red signal will show, and if this is ignored or not observed the automatic electric cut-off will function.

It should be emphasized, however, that this safety switch is provided to protect the unit when used for fluoroscopic and therapeutic work and prevent possible overheating of the head.

For the higher current techniques used in radiography, however, the heat generated at the target is not transferred rapidly enough to the oil to cause sufficient expansion to actuate the safety switch, and if radiographic milliamperages are used for too long a time the target of the tube may be cracked or melted before there is sufficient increase in the temperature of the oil, and therefore the limits of exposure as prescribed on the control panel must be carefully observed.

This head can be operated at 80 Kv., and 15 M.A. for radiography. The exposures can safely be made at the following rate:

Radiography: 15 M.A. 80 P.Kv.
10 secs. exposure.
40 secs. rest, indefinitely.

Fluoroscopically the unit can be operated as high as 80 Kv. at 5 M.A. for a period of 10 seconds, if it is given a rest period of two seconds. The ten-second exposure and two-second rest cycle can be continued indefinitely.

If, however, the operator ignores the two-second rest period, the unit will gradually overheat and the thermal shut-off will stop the exposure. So even if operated carelessly, the possibility of damage to the tube will be reduced to a minimum.

The cover of the shockproof head is provided with a flanged mounting ring concentric with the central x-ray beam. This flanged ring is designed to receive either a cone or the adjustable diaphragm of the table of Item No. 96215. The diaphragm casing itself also has a flanged mounting ring which will also adapt the same cone which is adaptable to the shockproof head. The cover of the shockproof head is provided also with receptacles for the push button or footswitch and the localization lamp. These receptacles are a duplicate of the receptacles on the control unit and are provided so that it is only necessary to have one cable leading from the control to the head. The auxiliary wires for the push button localizer lamp circuits are carried back through the multiconductor cable. It should be noted that this large cable is also provided with a snap fastener (59), Figure K, which

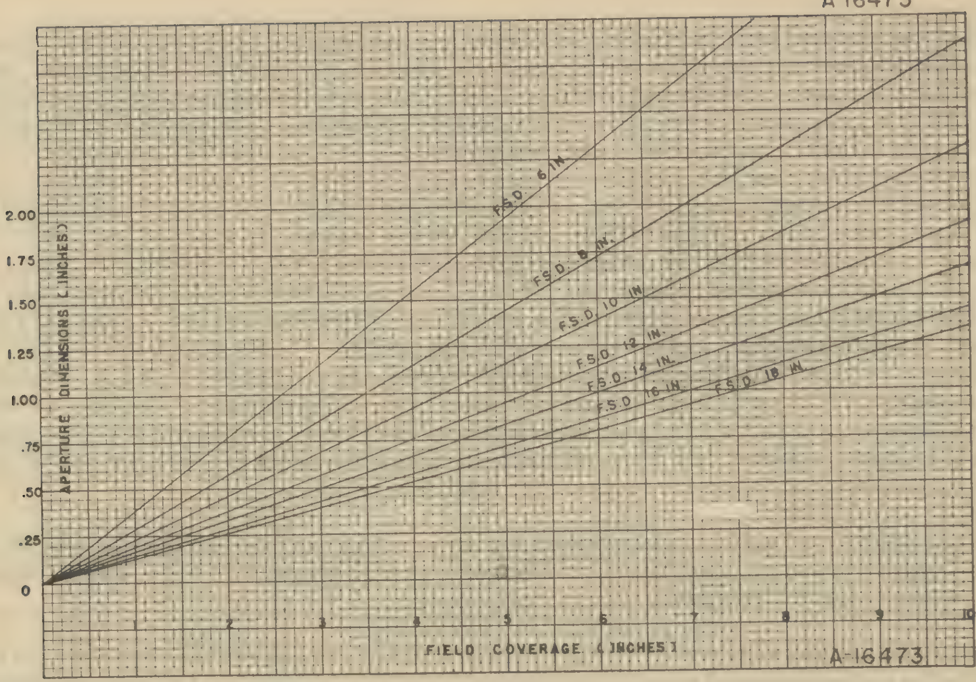

A-16473
APERTURE DIMENSIONS (INCHES)
2.00
1.75
1.50
1.25
1.00
.75
.50
.25
0
F.S.D. 6 IN.
F.S.D. 8 IN.
F.S.D. 10 IN.
F.S.D. 12 IN.
F.S.D. 14 IN.
F.S.D. 16 IN.
F.S.D. 18 IN.
1
2
3
4
5
6
7
8
9
10
FIELD COVERAGE (INCHES)
A-16473

FIG. Q

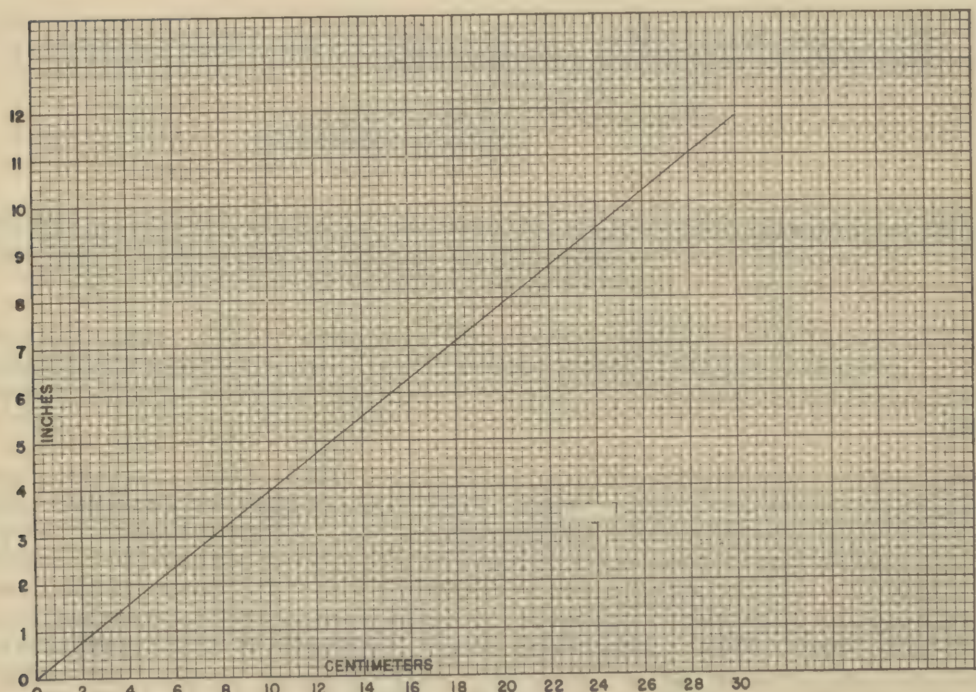

INCHES
12
11
10
9
8
7
6
5
4
3
2
1
0
CENTIMETERS
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30

FIG. T

engages one of the brace tie rods of the horizontal carriage of the table. The use of this snap fastener prevents the cable from dragging on the ground. The cover is also equipped with a bail type carrying handle (116), Figure M. to facilitate handling.

MOUNTING HANGER - The shockproof head is equipped with a mounting hanger (117), Figure M, made of fabricated steel arms securely bolted to an adapter which has been machined to fit the tube arm of the table of Item No. 96215 or the horizontal cross arm of a tubestand. The extremities or the arms of the hanger are equipped with bearing rings, one ring employs a locking clamp and lever (118), while the other end employs a closed bearing. Both sides of the head are equipped with an angulation scale indicating the degrees of rotation of the unit about its axis. The center or swivel bearing of the hanger is equipped with a locking clamp and wing screw which acts as a retaining clamp when partially released and as a lock against rotation when drawn down tightly. This clamp also employs a notched center section which acts as an indicator against the scale when used with a horizontal arm of the tubestand.

When attaching the shockproof head under the table the head should be positioned in the hanger so that the push button receptacle and the localization lamp receptacle are facing inside of the yoke so that the proper connection of these accessories can be made. For attaching the head to the table, see Figure C.

FILTERS AND APERTURE PLATES - The shockproof head is supplied with a built-in filter slide (119), Figure M, which will accommodate up to 3 mm. of filter. The filters are held in position by means of an indexing spring clip which engages a notch in the side of the filter. The lead aperture plates are engaged in like manner. As a precautionary measure against possible burns, the unit is equipped with a permanent .5 mm. aluminum filter secured to the housing proper, which cannot be removed.

The unit is supplied with one ¼ mm. of aluminum filter which has been anodized red to identify the thickness, one ½ mm. of aluminum filter which can be identified by its amber color, and 1 mm. of aluminum filter which can be identified by its green color.

In addition there is supplied two 1/16" lead aperture plates, on one surface of which are inscribed the center lines of x-ray beam. It is relatively simple to cut a given area proportionate to some selected distance.

PREPARATION OF LEAD ALLOY APERTURE PLATES - In order to use these plates for therapy work, it will be necessary to provide them with an opening to confine the radiation to the specific area which is being treated. The size of the aperture will depend also on the treatment distance. The chart, Figure Q, shows the coverage plotted against aperture dimensions for distances of 6, 8, 10, 12 and 14 inches. As an example, let it be assumed that the treatment distance is 10" and the area to be treated is 4" x 6". If we follow the curve of 10" F.S.D., the 4" point will correspond to an aperture opening of 15/16", and 6" point to an aperture of 1-3/8". Then by using the cross lines punched in the lead plate as the center of radiation, an aperture the size as determined above 15/16" x 1-3/8" will give the required field of radiation 4" x 6" at 10" F.S.D.

CAUTION: The filter is a very important part of therapy work, and it should be checked before starting each exposure.

As a convenience, chart Figure "T" may be used as a means of quickly changing inches to centimeters, if the technique used is specified in this system.

SPARE X-RAY TUBE - The spare x-ray tube (31), Figure 1, is packed in Chest No. 2 with the head and the control. This tube is mounted on a cradle and should it become necessary to replace a defective or burned out tube, this can be done in the field without affecting future successful operation of the head, if extreme care is exercised in following the instructions pertaining to that operation. A set of these instructions will be found under the main cover of the shockproof head together with a spare gasket and the tools necessary for readjusting the expansion chambers. This operation can be performed with a loss of only a few drops of oil, and if properly executed the head may be resealed without the slightest trace of an air bubble. It must be understood that an air bubble may cause failure of either tube or transformer.

Oil is not removed from the head when installing a new tube. If, however, through an accident more than a spoonful of oil is lost, this can be replaced by obtaining clean, clear, absolutely moisture-free medicinal oil. It must not be taken from a container which has been left open and exposed to the air. It should not be removed from a bottle which anyone has had to his mouth and admitted any moisture.

The spare x-ray tube should be removed from the chest in its metal container and attached to the table leg so that it will be always available regardless of where the chests are stored.

CHANGING AN X-RAY TUBE - If, after careful testing, it is found that the x-ray tube is gassy or punctured or otherwise defective, it will be necessary to change the tube in the head. If this is done very carefully, no additional oil will be required. If by accident some oil is spilled or lost, add only clear, clean, dry medicinal oil.

In changing the tube, remove the tube head to a clean, dry, well lighted area and then remove the top cover (60), Figure M, by taking out the four screws (61), holding it to the tube head assembly. Then remove the two sylphon adjusting screws found threaded into a pair of bosses in such a way as to retain the tube removal port gasket. Also remove the small eyedropper. Then turn the tube head on end with the tube anode end or removal port (120) up.

Support the head by blocking in a perfectly solid and level position. Then insert the two bellows adjusting screws in the two sylphons and tighten with fingers. The thumb nuts are next run down to the sylphon covers and then turned five turns additional. This puts tension on the bellows and tends to create a vacuum in the head so that when the tube is removed the oil level will be lowered when the cover is opened instead of tending to overflow.

Then remove the three button head screws (121) holding the cover and remove the metal inner cover plate with the flat circular springs attached. The flat neoprene gasket makes this cover stick fairly hard so that it may be necessary to carefully pry the inner cover off with your screw driver. The oil will then be exposed so you can see the anode end of the x-ray tube.

Before touching the oil BE SURE YOUR FINGERS ARE CLEAN AND DRY. Dirt or moisture, even in very small amounts, will ruin the oil and cause spark-overs and possible insulation failures. The tube and cradle can be lifted out of the oil by first removing the black fibre thumb screw holding the light colored moulded x-ray tube cradle to the high-tension transformer assembly. In putting the fingers in the oil be sure that they do not raise the oil level above the flange on the tank and allow the oil to spill. If it appears as though this will happen, tighten the

sylphon chambers still further with the thumb nuts, and thus lower the oil level a little more.

Remember that no oil must be lost. Drain every possible drop back into the tank. In removing the old tube, raise it very slowly. Allow it to drain and drip as long as possible. When it stops dripping, rapidly up-end the tube so as to empty the oil in the anode stem of the tube back into the tank and drain some more. Allow all oil to drain from the fingers. GET ALL THE OIL BACK INTO THE TANK.

After the new tube has been removed from its container, thoroughly clean and polish it. Then handle carefully and do not touch the glass part. If the tube is put into the tank immediately, there will be air trapped in the hollow cathode neck of the tube which would be very difficult to remove. It is necessary, therefore, to use the small eyedropper and very carefully fill this cathode end completely full of oil. The eyedropper can be used for this purpose, removing the oil from the tube head.

Then, holding the tube cathode end up, lower it beside the tank so that it can be quickly but carefully turned over, inserting the filled cathode end into the transformer oil without spilling any oil. If you haven't done this before it would be recommended that you practice on the old tube first.

Then carefully and very slowly lower the tube into the oil so that it indexes in the cathode slot in the botton of the tubestand. By looking through the radiation window, the tube can be centered during this lowering process. When properly indexed, fasten in place with the fibre screw and again drain the fingers of all oil.

The sylphon pressure should be slowly released so as to raise the oil level EXACTLY EVEN with the gasket flange. If no oil has been lost this can be readily done by removing all tension from the bellows. If a little oil has been lost it may be necessary to put pressure on the bellows to raise the oil level. If more than 1/16" movement of the bellows, beyond their free position, is necessary, additional oil must be added. With the oil level exactly even with the gasket flange, replace the gasket and gasket cover and tighten down outer cover evenly. Then rock head end for end and examine for air bubbles through transparent window. Small bubbles trapped around the edge of the windows are permissable only if the head is to be used with port up, such as for fluoroscopy or localization. Otherwise, the air bubbles will float into the high-voltage path and cause sparkovers. If air must be removed, it will be necessary to remove filler plug on top of head and add a few more drops of oil to replace the air. If the entire procedure is done very carefully this should not be necessary.

Return the spare gasket if not used, or the old one (if the new has been used) together with the bellows adjusting screws, thumb nuts and eyedropper to their proper places under the cover of the head and then replace the cover. Be sure to test the head carefully at reduced voltages before continuing with routine operation.

The defective x-ray tube should be carefully packed in the spare tube container, and returned to the nearest Medical Supply Depot together with a requisition for a new replacement tube.

CAPACITY WITH GASOLINE ELECTRIC GENERATOR ITEM NO. 96060

In order to protect the x-ray transformer and all of its insulation as well as the x-ray tube, it is important that the inverse voltage as well as the surge voltage be held to a minimum. If this equipment is operated on an unsuitable gasoline electric generator, there will be no apparent evidence of improper operation, but

FIG. U

the excessive voltage which may be present may, in time, cause failure of the equipment. It is, therefore, recommended that this equipment never be operated from any gasoline electric generator unless it has been definitely approved for this purpose. At the present time, the only approved generator is Item No. 96060. At some later time, a lighter weight generator may be available. It is equally important to understand that this equipment can not be operated from a direct current source, and that it must be operated on lines whose frequency lies within 50 and 60 cycles. If it is operated on a 60 cycle line, or with Item No. 96060 gasoline electric generator, the following is the safe limit of operation fluoroscopically and radiographically:

For Fluoroscopy 5 M.A., 80 P.Kv. with 10 seconds exposure and 2 seconds rest period, indefinitely.

For Radiography 15 M.A., 80 P.Kv. for 10 seconds exposure and 40 seconds rest period, indefinitely.

If the unit is operated on a 50 cycle current source, the maximum P.Kv. should be reduced by 10 P.Kv. or the rest period between exposures should be doubled.

ELECTRICAL CONNECTIONS

The push button and plug (62), Figure U, will be located in Chest No. 3. This is used for fluoroscopy or localization instead of a footswitch to facilitate operation during localization and to eliminate the necessity of a footswitch which may be objectionable on soft or bumpy ground. The plug (63) should be dropped down through the center of the vertical tubular member (15), which is now supporting the screen

and the x-ray tube. When the plug emerges from the lower end of this, it should be connected to the receptacle provided on the top edge of the shockproof head facing the operator's side of the table and designated by the attached instructions.

This places the push button in a very convenient position for fluoroscopy. If the push button is now raised a few inches, the cord for the two localizer lights packed in the spare parts compartment in the horizontal carriage can also be lowered through the vertical tubular member. When properly installed it will provide current for the two localizer lamps, yet it will keep the cord in an out-of-the-way position. This cord (64), Figure K, is equipped with three plugs, two of them are close together. This is the bottom end of the cord. The plug having the two cords emerging should be lowered down through the vertical tubular member (15), Figure K, until it and the short cord plugs have dropped clear to the floor. This plug with two cords (65) can now be inserted into the receptacle provided for it along the edge of the shockproof head next to the push button plug. The plug on the remaining short cord at the bottom can plug into the receptacle on the underside of the foreign body localizer dial at (66). The plug at the top can now be inserted into the receptacle at the top of the screen skin distance gauge (42) as shown at (67), Figure K. The connections for the push button and localizer lights are contained in the main control to tube head cable. No additional cables are necessary.

Whenever the main switch of the control is turned on, and the x-ray exposure is off, these two lights should be illuminated (incidentally, spare bulbs are packed in the spare parts kit in the horizontal carriage). A notch will be noticed in the top of the vertical tubular column (15). The cord, when inserted in this notch, will leave room to put the push button back into place, mounted on the top of the vertical tubular member as shown in Figure K.

The main line cable (68), Figure K, can now be plugged into the control. The cable (69) to connect the control to the shockproof head can be plugged into position both at the control and at the head, and clip (59) snapped to the brace rod as shown.

The hand timer (122) used for radiography (which is packed in Chest No. 3) is plugged into the right-hand side of the control and can be hung on the hook provided on either side of the control. A localizer light receptacle is also provided on the control.

OPERATION OF ITEM NO. 96215

It is highly important that the depth gauge and skin marker (42), Figure G, is treated in a careful manner, because if it is bent it may cause difficulties in future operation; and it certainly will cause errors in foreign body depth location unless the error is cancelled out through the adjustment provided at (70) at the end of its arm. There is a well provided at this point in which are pads, which can be saturated with iodine so as to use this as a skin marker. At this point (70) will be noticed thumb adjusting nuts to permit raising and lowering the point which comes in contact with the skin. If this is adjusted up or down to properly coincide with the calibration gauge, supplied with each unit, a high degree of accuracy in foreign body localization is possible. This is described in more detail in the chapter devoted to foreign body localization.

It is recommended that when moving the screen, pressure for this movement be applied to the vertical column (15), Figure K, rather than to the screen itself. This will reduce the tendency of developing wear and looseness or play in the screen mechanism. It will be found most convenient for the left hand will be directly over the fluoroscopic push button (62), Figure K. When moving the assembly in this manner, the x-ray tube and the screen can, of course, be moved up and down so as to

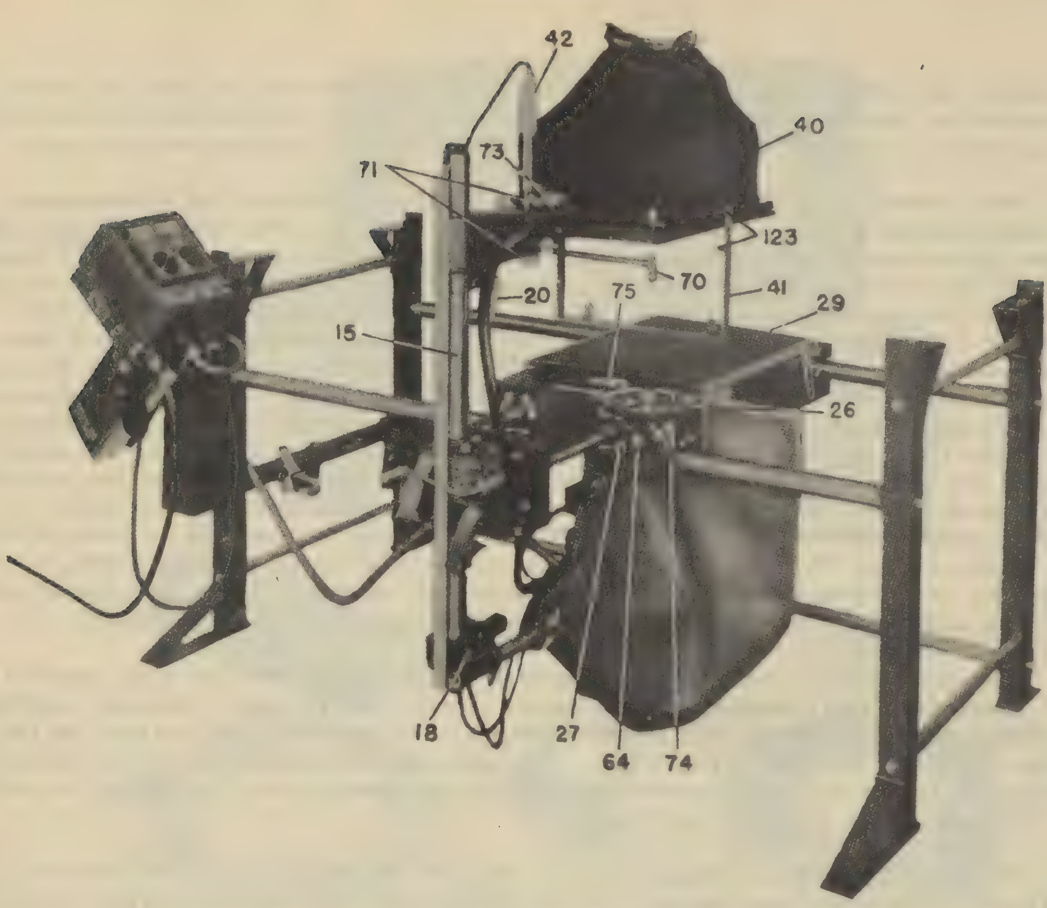


FIG. R

bring the screen close to the skin. It will, however, be noticed that to keep the shockproof head or tube from being cranked down until it strikes the ground, a stop is provided to limit vertical travel. This stop is controlled by a lever (17), Figure K, on the side of the elevating mechanism housing through which the vertical column travels. There are two positions for this lever. One is fluoroscopic and the other is radiographic. In the fluoroscopic position, it prevents raising and lowering the tube beyond proper limits. When in the radiographic position, with the tube or head installed on the radiographic extension tubestand and above the table, it permits a greater range of vertical travel of the spot for radiography. This control or limit stop should by all means be placed in the proper position for the work to be done. It is also very important to understand that this stop lever must be placed in the radiographic position when assembling or disassembling the vertical tubular member into its vertical guides in the elevating mechanism housing as indicated by the instructions beneath the lever.

FOREIGN BODY LOCALIZATION

For this work, it is necessary to have the localizer dial gear (26), Figure R, engage with the rack and the thumb screw (27) pulled up tight as well as to have the screen-skin distance gauge and marker properly in place and the cord (64) connected to the depth gauge and localizer dial.

Before proceeding with the actual localization, it is necessary to be sure that the distance from the focal spot of the tube to the screen is exactly 66 cm. Due to the difficulty in measuring this distance, a calibration gauge is supplied with the unit. This is a "U" shaped member (41), Figure R, with hooks provided for hanging

FIG. P

it up when not in use and with four pins (123), Figure R, attached to it to support it from the screen frame. The two pins close to the open end of the "U" can be used first by hanging this "U" shaped member with the open end up on the frame of the screen, as shown in Figure R. This should be done with a daylight hood installed. The closed end of the "U" has two holes in it, each carrying a cross hair. It will be noted that the screen carries three cross lines. Operating the unit fluoroscopically with the diaphragm closed down slightly so as to be certain not to ray over the edge of the screen, be sure that the screen is illuminated slightly further than the two outside lines. The calibration gauge should now be moved one way or the other until the shadow from one of the pins in the lower portion of the "U" casts its image directly on one of the lines of the screen. Now note whether the image of the second cross hair is directly on the other extreme line of the screen. If it is not in direct register, it indicates that the screen is either too close or too far from the focal point of the tube. Two thumb screws as at (71) are provided in the arm which supports the screen assembly - one above and one below. If you loosen one and tighten the other, you can raise or lower the screen. This adjustment should be made until both cross hair shadows are in direct register with the two outside lines on the screen. At this time, the two thumb screws must be tightened so that they will not lose their adjustment. After tightening, recheck alignment.

If the calibration gauge is slipped off the screen frame and raised and slipped back again so that this time it is supported between two pins farthest from the open end of the "U", it will be possible to properly adjust the screen-skin distance

gauge, which should not be swung into such position that the skin marker at the end of the arm is in the approximate center of the screen. Lower it down then until it rests on the calibration gauge, without supporting it with the hands, allowing the full weight to rest on the gauge. When in contact at this point, the vertical scale of the skin marker (42) as read against the cross wire in the center of the window should now read 14.7 cm. If it reads more or less, the lock nut at (70), Figure R, should be loosened at the skin marker, and the marker should be raised or lowered until finally it is adjusted so that when the part which will come in contact with the skin is touching the gauge, the scale must read 14.7 cm. as is indicated by the instructions attached to the gauge. Lock the nut at (70) and recheck.

It will be noticed that the foreign body localizer dial attached to the table carriage has red graduations half way around it. It will also be noticed that one edge of the screen frame is marked with "red . This simply indicates which side of the scale should be used in relation to the edge of the screen or the hair line on that side. THE UNIT SHOULD ALWAYS BE CHECKED WITH THE FLUOROSCOPIC HOOD (40) IN POSITION IN ORDER TO OBTAIN MAXIMUM ACCURACY.

PROCEDURE IN LOCALIZATION

An outline of the procedure and an example is shown in Figure S.

In order to localize a foreign body, proceed as follows:

(1) Lock the fluoroscopic screen against horizontal rotation about the vertical column (15) by means of the locking lever (20), Figure R, and against rotation in its own axis by localizer lock (73).

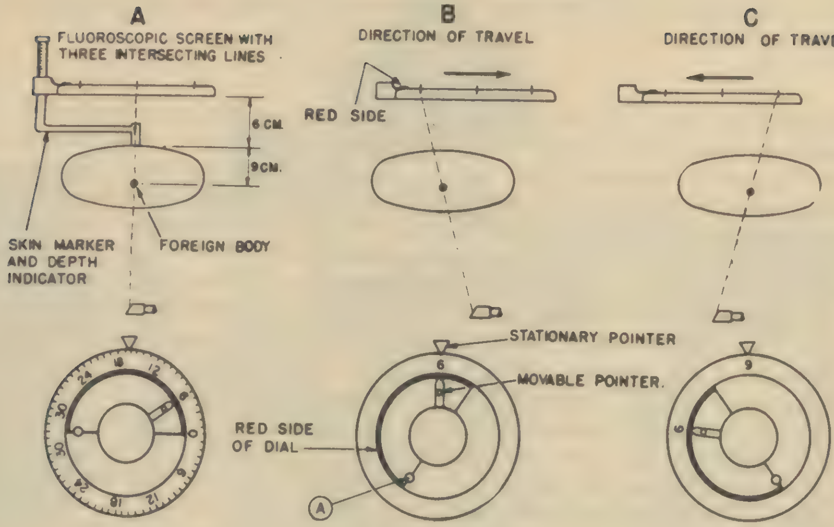
(2) With the patient on the stretcher adjust the vertical column by means of the crank (18) up or down until there is approximately three inches between the underside of the screen and the patient. With this clearance sufficient room will be had for the free use of the skin marker (42), Figure R.

(3) Longitudinal motion of the screen is accomplished by turning knob (29), which is postively geared to the rack to propel the entire horizontal carriage. With the lock (74) in the localizer dial (26) and the lock (75) free, adjust the carriage horizontally. With the lock (74) in the localizer dial (26) and the lock (75) free, adjust the carriage horizontally until the image of the foreign body is accurately located in the center cross hair in the screen. Additional crosswise adjustment may be had by shifting the litter on the table if the foreign body cannot be made to fall on the central cross hair on the screen. Now lock the cross travel of the horizontal carriage by means of the lever (75) and also lock the lengthwise travel by means of the lever (74).

(4) Be sure that the marking pad at (70) has been moistened with iodine or ink. The well above the pad is packed with fillers so that if desirable the well can be filled with the marking fluid. Then lift slightly and rotate the skin marker gauge (42) counter-clockwise as far as it will go. The marking pad should then lie directly beneath the center cross hair in the screen. Now lower the pad until it just touches the patient's skin and read the depth of the skin below the fluoroscopic screen on the scale of the depth marker. It is important that this operation be performed accurately since any errors will be directly added to the final depth.

(5) Take the readings of the depth of the skin below the screen obtained on the gauge (42) and then lift the depth gauge as far as it will go and rotate in a clockwise manner in order to remove it from the fluoroscopic field. It will drop slightly and remain locked out of the way. Then adjust the movable pointer (76), Figure P, to this corresponding depth on the red side of the dial (77).

PROCEDURE DIAGRAM



1. ALIGN FOREIGN BODY TO CENTRAL INTERSECTING LINES.
2. ROTATE SKIN MARKER OVER FOREIGN BODY AND DROP DOWN GENTLY UNTIL PAD TOUCHES SKIN. READ SKIN-SCREEN DISTANCE ON SCALE. RAISE MARKER UP AND ROTATE OUT OF FIELD.
3. INDICATE SKIN-SCREEN DISTANCE READ IN PARAGRAPH NO.2 ON RED SIDE OF DIAL WITH MOVABLE POINTER.
4. ALIGN FOREIGN BODY WITH OUTER INTERSECTING LINE ON RED SIDE OF SCREEN.
5. TURN DIAL BY MEANS OF KNOB "A" UNTIL MOVABLE AND STATIONARY POINTERS COINCIDE.
6. ALIGN FOREIGN BODY WITH OPPOSITE INTERSECTING LINE. READ DEPTH OF FOREIGN BODY BENEATH MARK ON SKIN INDICATED BY STATIONARY POINTER ON DIAL.
7. FIGURES IN ABOVE DIAGRAM INDICATE A CASE WHERE SKIN-SCREEN DISTANCE = 6 CM. AND DEPTH OF FOREIGN OBJECT = 9 CM.

NOTE:
BEFORE PROCEEDING WITH LOCALIZATION CHECK THE ACCURACY OF THIS EQUIPMENT WITH CHECKING GUAGE 41 FIG. G.

FIG. S

(6) Unlock the lengthwise motion of the screen by means of the lever (74), Figure P, keeping the crosswise motion locked, and by means of the knob (29) drive the unit until the image of the foreign body coincides with the cross hair at the "red" side of the fluoroscopic screen. Care must always be observed that the movable pointer (76), Figure P, should not be shifted once the depth of the patient's skin below the screen is recorded. Otherwise errors will be introduced.

(7) Now lock the unit against motion by means of the lever (74) and by means of the small knob (78) rotate the dial (77) and the pointer (76) together until the pointer (76) coincides with the stationary pointer (79). By this operation the skin-screen distance is automatically subtracted from the screen foreign body distance.

(8) Now loosen the lever (74) and by means of the knob (28) drive the unit in the opposite direction until the image of the foreign body coincides with the cross hair away from the "red" side of the fluoroscopic screen. Lock the unit against motion by means of lever (74) and read directly as indicated by the stationary pointer (79) the depth of the foreign body below the mark placed on the patient's skin. It is to be noted that if the above procedure has been followed the depth

of the foreign body below the patient's skin will ALWAYS be indicated on the black side of the dial (77).

RADIOGRAPHY

If radiographic work is to be done, the radiographic tubestand, Figure H, should be removed from its support between the table legs described elsewhere. Before this can be installed on the top of the vertical column, the cord used for the illumination of the screen-skin depth gauge and the push button must be removed. With the tubestand in the proper position, the vertical travel stop lever (16), Figure K, should now be turned to the radiographic position. It will then be possible to crank the assembly into the lowest position, allowing the head to rest on the floor. It can then readily be disengaged by moving the carriage out of the way. The head can be lifted out from between the rails and installed on its arm at the top of the tubestand as shown in Figure H. It will be noted that there are two positions (80 and 81) in the radiographic tubestand (22), one for horizontal radiography and one for vertical radiography into which it can be mounted as indicated by the instruction label. In the upper or longer fitting (80), Figure H, in the tubestand are two positions, one of which is correct for the Airflow shockproof head and the other for the Airflow tube and the proper position is indicated by the instructions attached. If the arm (21) is not placed in the right position, it will be noticed that the tube cannot be made to travel crosswise an equal distance from center of the table. When removing either the tube or the shockproof head, the diaphragm and x-ray protective shield must be removed from the tube or head. So as to make it unnecessary to remove this shield and find a place to put it, two fittings (82), Figure H, are provided on the side of the horizontal carriage frame. The protective apron can be hung from the fittings (82) as shown in Figure H at the side of the carriage and the diaphragm control can be hung on the brace rods that stiffen the carriage (the rods with the two eccentric fasteners) as shown in Figure G. All of this can be done still leaving the diaphragm control in its normal position and the opaque apron still supported by the carriage.

By means of the crank, the head can be raised or lowered for all normal ranges of radiographic distances. If it should become necessary to take a horizontal radiograph at approximately 6 feet from the subject, this can be accomplished by turning the tubestand and the head so that it does not center over the table, but centers over a litter placed on the ground beside the table. When this is done, care must be exercised that this overhanging weight does not accidentally tip the table.

For horizontal radiography the cassette should be placed upon the tray (88), Figure H, and centered with the target of the tube. It is necessary to observe that the target in the case of the shockproof head is approximately 1¼" off center of the arm (21). The cassette can be elevated in order to bring it as close to the patient as possible by grasping the side of the frame carrying the tray (88) and lifting it to the desired position, being sure that ratchet levers (89) engage the pins. In lowering the tray to the normal position it is necessary to release both ratchet levers (89). Of course, because of the number of teeth on the ratchet levers, intermediate steps of elevation may be had. The grid (125) should be placed upon the cassette. Be sure that the proper side faces the tube. Always store the grid when not in use, with the screen.

In order to bring the position of the source of x-rays within the range of adjustment of a normal chest, the shockproof head or x-ray tube should be installed in the position (81) of the tubestand (22), Figure H, and the head pointed either to the right or to the left longitudinally of the table unit. Therefore, by placing the patient at either end of the table, vertical radiography can be accomplished and the focal distance can be altered by shifting the carriage mechanism longitudinally upon the table.

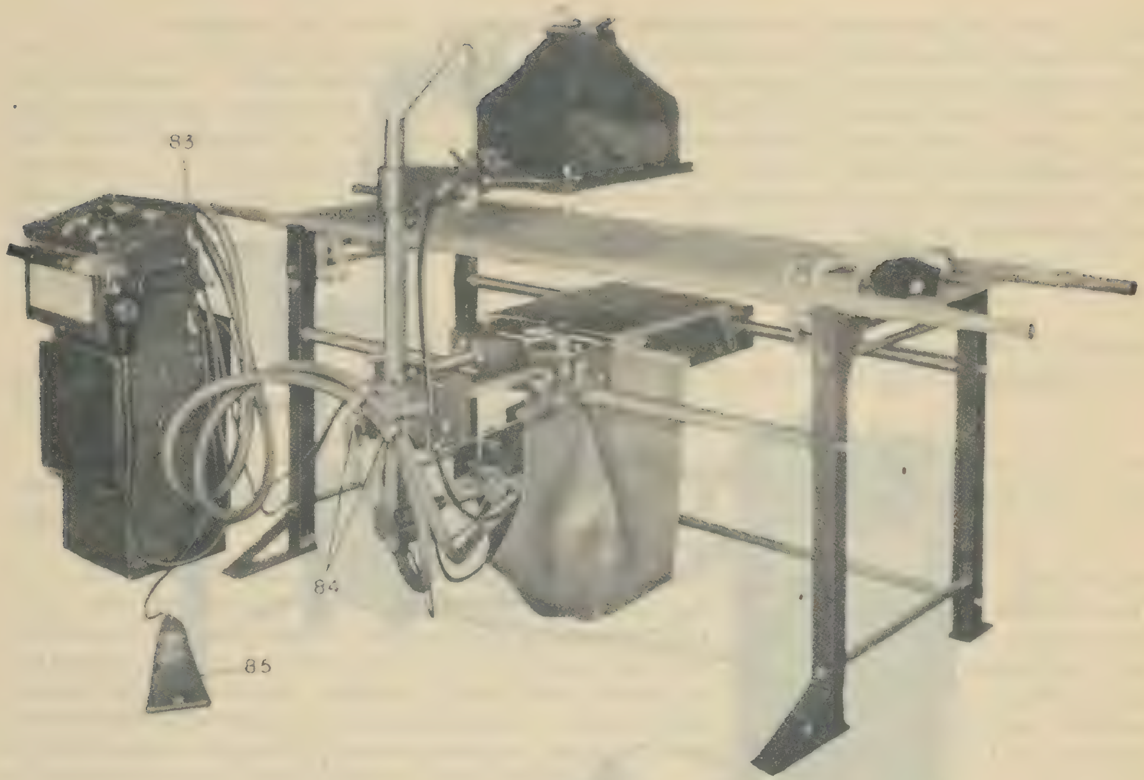


FIG. N

Of course, the cone can be installed in the head, in the cone holder provided when the head is used over the table.

USE OF TABLE WITH GENERATOR OF ITEM NO. 96085 FIELD UNIT

If it is desired to operate this table with the Airflow tube, the transformer, control and shockproof cables, of the Army Field X-Ray Unit, it will be found to be extremely simple to handle. The tube is installed as described elsewhere either above or below the table as in Figure N or O. The transformer and control should be placed at the end of the table that would be at your left if you stood at the side of the table facing the localizer dial and it should be placed about one foot beyond the leg of the table and six inches away from the leg of the table. The control should be mounted on the top of the transformer and the two should be so turned that the back of the control and the back of the transformer are facing the space at the left end of the table. If the unit is not placed in this position, it will not provide the best position for the shockproof and other cables. It will not be as convenient for the operator to adjust the controls. If it is in this position, the shockproof cables and the smaller gauge or motor cables to the tube should be supported by the canvas straps on the back of the control as at (83), Figure N or O. This will remove the strain from the cables and support them in a graceful rather than a sharp bend. It will be noticed that canvas straps (84) are provided on the elevating mechanism housing adjacent to the vertical cranking mechanism on the table when using the table fluoroscopically.

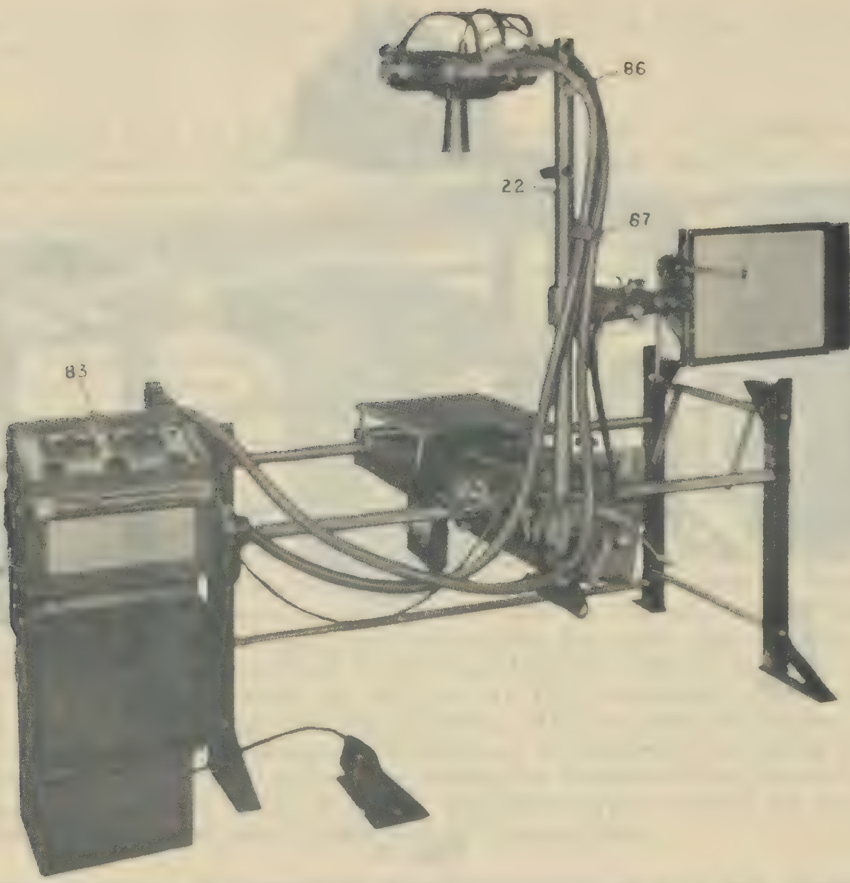


FIG. O

The shockproof cables and the motor cables should be supported at this point, and if properly done, the cables will assume large radius curves which will protect them. In the event that the table is used in this manner, there will be available with the transformer and control a footswitch (85) instead of the push button which would be available with the Airflow shockproof head.

Packed in the tool compartment of the horizontal carriage is an extension cord for a localizer circuit. This cord can only be used with Item No. 96085 and it will be found that the regular cord is too short to reach to the control if the transformer is placed in the proper relationship to the table.

The instructions covering the operation of the tube, transformer, and control of Item No. 96085 should be followed insofar as they apply, but these instructions will still cover the use of the Airflow tube on this table.

Canvas straps (86 and 87) are also provided for mounting the cables of the Airflow shockproof tube of Item No. 96085 to the radiographic tubestand (22), Figure O, for horizontal or vertical radiography. These canvas straps will properly support the cables at the upper extremity of the radiographic tubestand, and will prevent the cables from sagging or interfering with the operation of the unit.

POSSIBLE OPERATING DIFFICULTIES

If it appears that there is something wrong with the equipment and that x-rays are not being generated, don't jump to the conclusion that the trouble lies within the equipment. First make absolutely certain that there is electrical current at the source of connection to which the main line cable is plugged in. A fuse may be blown somewhere, or a switch may have been turned off since the unit was last operated. It is possible that failure to operate may be caused by a connection which has come apart, such as one of the plug-in connections at the various receptacles. Examine the main line connection at each end. Examine the control to transformer cable at each end. Examine the push button connection where it is connected either to the head or to the control.

If the unit fails to produce x-ray, but both the milliammeter and voltmeter indicate the passage of current, it is quite possible that the lead diaphragm is in the closed position. This mistake frequently happens.

The following are other suggestions relative to failures in operation. Study them carefully. Try to analyze the symptoms which are present, for this will help greatly in tracing the trouble.

In case of extreme emergency it may be desirable or necessary to operate the unit even though both meters have become defective. To this end, it would be well to record in some readily accessible place the setting of the major and minor kilovoltage selector and the setting of the pointer for five milliampere operation. It should be emphasized, however, that this operation should only be attempted in an emergency and should be limited only to fluoroscopic work. Also, since the settings of the selectors and filament control vary from one line to another, the settings as recorded will only apply for one condition.

If the fuses in the wall meter box blow out repeatedly during operation, check the fuse capacity to be certain that they are heavy enough for the requirements. They should be at least 15 ampere capacity for 15 milliampere work.

If the fuses blow out immediately on turning on main switch:

1. Check source of current TO BE SURE that the supply is 50-60 CYCLES, and 100-130 or 200-240 VOLTS; be certain that the Supply is NOT D.C.
2. Check the line compensator adjuster on the side of the control to be certain that the voltmeter needle coincides with the red line on the voltmeter scale, when the conditions described are met.

If the voltmeter does not indicate, make sure:

1. That the line cable is properly plugged into the receptacle of the supply-line.
2. That there is voltage at this source of supply.
3. That there are no blown fuses.
4. That there is no break in the conductors within the line cable. This is most apt to occur at or near the point of connection of the cables to the line plug or control plug.
5. That a voltage selector switch is not set on a dead button.
6. That the main switch is turned on.
7. If the pilot light and meter illumination lamps are lighted, and all the above have been tried, check the wires leading to the voltmeter to be sure there are no open circuits or loose connections. If the connections are all intact, the trouble is probably a loose connection or open circuit in the meter, and it should be replaced.

If the milliammeter does not indicate:

1. Make sure that the x-ray filament is energized - this can be checked by throwing the filament check switch to "check filament" position and if the meter swings off scale, it indicates that the filament circuit of the tube is open.
2. Examine the plug connections of the Airflow tube head. Be sure that it is properly connected and that no wires are broken off. This can usually be determined by slightly flexing the cable near the end with the idea that if a wire is broken, its ends may be brought in contact by flexation, lighting the filament temporarily.
3. Make sure that the timer, footswitch, or push button are properly connected and that good contact is extablished at this point. Further, that there is no failure in the timer or footswitch.
4. That the circuit breaker is not tripped. Try the reset switch.
5. If the footswitch or push button is being used, be sure that the radiographic fluoroscopic safety switch is set to the fluoroscopic position.
6. If the timer is being used, be sure that the radiographic fluoroscopic safety switch is set to radiography, and timer set to some time interval.
7. Make certain that the tube motors cable is properly plugged into the tube, and also into control unit (when using the Airflow tube of Item No. 96085). If this cable is disconnected, the safety relay remains open and the circuit which supplies current to the main contactor is held open.
8. Make sure that the plug on the cord leading to the thermal safety switch is properly plugged in (when using the Airflow tube of Item No. 96085).
9. If the main contactor closes, and the milliammeter does not indicate there is probably a loose connection of an open circuit in the wiring leading up to the meter or possibly in the meter itself.
10. If the filament of the x-ray tube does not light the milliammeter will not read. The filament meter will read at full scale value if the filament circuit is open. It can be definitely checked by removing the built-in filter which covers the transparent window.

Milliameter indicates, but fluctuates:

1. Slight fluctuation may be expected because of line voltage changes. This can usually be traced to line voltage by watching the voltmeter and the milliammeter at the same time. If both show a change but if the change is greater at the milliammeter than at voltmeter, it greatly indicates fluctuation in line voltage. It may also indicate loose connection of the line cable or transformer cable.
2. If the milliammeter fluctuates severely, and the voltmeter is quite steady, it may indicate a loose connection in the filament primary circuit and the tubehead cable and plug should be checked for a defective wire; it may also indicate a loose connection in the secondary filament transformer. It may also indicate a poor connection or an open circuit in the x-ray tube, and in this instance, it is advisable to replace the x-ray tube.
3. Severe fluctuations in milliamperage may indicate a gassy x-ray tube. If all the points have been checked and if visible examination of the tube through the port shows discoloration on the inside of the glass of the x-ray tube insert, or shows the copper anode, it is safe to assume that the tube is gassy and was overheated through prolonged over-exposure.
4. If the milliammeter moves a division or so and then vibrates severely, it indicates that the x-ray tube is very gassy or puctured.

If the circuit-breaker kicks out constantly:

1. It may be caused by a defective x-ray tube. In this event, it will usually be noticed that the pointer of the milliammeter has a tendency to fly across the scale and then back to zero as the breaker opens the circuit.
2. It may indicate a short circuit within the control or within the connecting cable between the control and tube head. This would be most apt to happen at the connections between the cable and the Airflow tube head.
3. It may indicate a breakdown of insulation, coils, etc., within the Airflow head. Under the very best conditions, where service is available, the cover might be removed and the transformer assembly withdrawn from the tank. However, this should never be attempted unless experienced help and the best of facilities are available.
4. It may indicate a defective milliammeter because the actual milliamperage passing through the tube may be more than that indicated by the milliammeter if the meter is defective.
5. It may merely indicate that the setting of the circuit is incorrect and should be readjusted to trip at the correct values. Before the adjustments are changed be sure to check all other possibilities to avoid damaging the unit.

Never connect the main line cable to a source of current supply without being positive that the voltage and frequency are right.

Never connect the line cable to a source of supply unless the main switch is shut off.

Never permit starting of the gasoline electric generator without having the main switch shut off.

Never connect or remove the Airflow tube head until the main line switch is shut off and the main line cable disconnected from the source of supply.

Never use the equipment without adequate x-ray protection.

If the equipment has been operating for some period of time and then refuses to operate, don't jump at the conclusion that something has gone wrong. It may only be the automatic tube safety shut-off. Therefore, note the temperature of the tube housing. If it feels quite hot to the hand, it may simply be this. Of course, it is well to make sure that the main line switch, the circuit breaker, and the selector switches together with all cords, plugs, footswitches and timers are normal.

Don't forget when working with the gasoline electric generator, it will only run approximately two hours on one filling of fuel. Regular intervals of filling will, therefore, prevent shut-down, at periods when the equipment is needed most. Be sure to read and become thoroughly familiar with the care and operating instructions pertaining to this plant, especially that regarding its lubrication.

Don't forget that a ½ mm. of aluminum safety filter is built into the tube head directly in front of the aperture. If for any reason you remove this, it should be replaced to prevent possible burns.

Don't forget to make use of the lead aperture plates, which can easily be cut out with a pocket knife to provide any desired field area and reduce the total area of radiation to safe limits.

Don't attempt to do therapy work with the hand timer as the exposure switch. The footswitch should be used for this. For treatment work, a weight can be placed on the footswitch. Operating in this manner, it will be necessary to set the radiographic fluoroscopic switch on fluoroscopy, which automatically limits the milliamperage. On Item No. 96215 a push button is used in place of the footswitch.

Don't forget that different lines or source of power and different x-ray tubes will upset any pre-reading filament chart that you may prepare.

Don't forget that because of differences in line voltage drop on different supplies that the kilovoltmeter cannot be made to read accurately as a pre-reading device. It must be read with a load, and the load must be adjusted to the value desired, and the kilovoltage selector switches finally adjusted to the desired kilovoltage. These switches must never be adjusted while the load is on.

Don't forget to return the tools and spare parts to the space provided for them in the base of the control or the spare parts compartment in the horizontal carriage of the table so that they will be available in an emergency.

Don't forget that this is half wave self-rectified equipment, and that current is passing through the x-ray tube only on every other half wave. In other words, it is on half of the time. The milliammeter reads the average current. Therefore, when the unit is operating so that the milliammeter reads 15 M.A., this is the average current. Actually 30 M.A. is passing through the tube for half of the time giving the same effect radiographically as 15 M.A. if it were on full wave.

Don't forget to carefully retain and preserve the chests and all packing material protecting them from the elements if it is at all possible.

Be sure to attach ground clip to a good ground at the same time the main line plug is connected and check this point before beginning operation of the generator.

Don't forget that the fluoroscopic grid must face the x-ray tube as indicated by the instructions attached. Otherwise, cut-off will result and will be evidenced by the limited illumination of the fluoroscopic screen apparent under exposure of radiograph.

ADJUSTMENTS

CENTERING SCREEN LONGITUDINALLY - If the screen is not properly aligned parallel to the edge of the horizontal carriage, proceed as follows: on the shaft of the lock (30), Figure R, is a latch having an adjustable screw bearing against the side of the rack on the vertical column. The housing through which this shaft passes has a similar screw. Adjust these alternately until the screen locks parallel to the side of the horizontal carriage. Check the operation of the lock to be sure that it operates properly. The operation of the lock is such that the latch will always free itself. However, if the friction against the latch is insufficient, the operation may be faulty. Check the friction of the latch on the shaft, and if necessary adjust by removing the cotter pin through the slotted head friction nut and adjust the nut until there is definite friction of the latch. Be sure that the cotter pin is replaced and that it passes through the slots in the friction nut.

PLAY IN THE VERTICAL COLUMN - In the two fittings, at the top and bottom of the gear housing of the horizontal carriage, are adjusting screws locked with nuts. These screws are intended to bear against the side of the rack on the vertical column to reduce any play of the assembly. If necessary, adjust these screws until they just bear against the rack without binding. Be sure to lock them with the lock nuts.

BRACE RODS - If the brace rods do not have good snap action they can be shortened or lengthened by adjusting the hooked end in the eccentrics. Be sure that the lock nut is tightened securely to maintain adjustment.

CENTERING MARKING PAD - If the marking pad at the extremity of the depth indicator and skin marked does not cast its shadow in register with the central cross hairs in the screen, proceed fluoroscopically as follows:

1. If the pad rotates too far or not far enough before striking the stop, loosen the set screw in the tubular member having the scale, and adjust the arm with the marking pad either clock or counter-clockwise until the pad lies beneath the cross hair. Tighten the set screw.
2. If the length of the arm seems too little or too great, adjust by loosening the set screw in the bottom of the fitting through which the arm passes. Be sure to tighten the set screw.

BEARINGS - Wherever necessary, eccentrics have been provided on the bearings in the carriage. These have been properly adjusted by the manufacturer. However, should they lose their adjustment, the necessary tools for their adjustment will be found in the spare parts compartment.

REPAIR OF UNITS

Before attempting to make any repairs, it is recommended that you first become completely familiar with the apparatus to be repaired. The instruction manual furnished with the x-ray unit should be thoroughly studied.

A complete and accurate diagnosis of the trouble is essential before attempting a repair. Do not jump at conclusions. Attack the problem from all angles. Prove to yourself by sound reasoning and by unbaised tests that a definite repair is necessary.

If, after your diagnosis of the trouble, you find that a definite repair part is needed, determine whether or not it is available in the spare parts kit in the control. The manufacturer has tried to anticipate the troubles you might have with this equipment. The selection of parts will not suffice in all instances, each, for example, as might occur if a unit is damaged by dropping or by some severe physical impact.

METERS - If one or both of the meters are defective, either from excess friction or because they have been accidentally burned out, it will, of course, be necessary to remove them.

After this metal framework has been removed with a screw driver and the rubber cushion pads carefully removed with it, the meter can be lifted out because the wiring connected to the meter is purposely made long enough to remove the meter without removing the entire control case. When replacing the meter, it is recommended that one lead be removed at a time and placed on the corresponding meter stud of the new meter. In this manner there will be no mistake of getting the meter leads reversed. If they are accidentally mixed up, it will be necessary to refer to the wiring diagram and to the color code on the leads to be sure of this, When replacing the meter be absolutely certain that the rubber cushion pads are carefully put back into place before putting the meter in place. IF REPLACEMENT METERS ARE AVAILABLE, DO NOT ATTEMPT THE REPAIR OF A METER BY OPENING THE METER CASE. THIS CAN BE DONE BY A QUALIFIED METER REPAIRMAN WITH THE PROPER INSTRUMENTS AVAILABLE. In extreme emergency the meters may be repaired by following the meter manufacturers' recommended procedure as follows:

The following instructions have been prepared for use by untrained instrument servicemen operating under emergency conditions.

In general, an electrical indicating instrument can be cleaned and re-serviced in a majority of emergency cases for minor faults by any individual familiar with fine, neat workmanship as for example, watchmakers. The equipment necessary is listed below:

Small jeweler's screwdriver such as found in sewing machine kits or surgical instrument repair kits.
Small scissors such as used in surgical work or in fine sewing.
Small pliers or heavy tweezers.
Fine tweezers as used in some first-aid kit or in a woman's make-up kit as eyebrow tweezers.
Fine steel needle with a small wood or rubber (pencil eraser) handle.
Small soldering iron as made from heavy copper wire and wooden handle.

Before attempting to perform any repairs on the instrument mechanism, a clean level place should be prepared as free from drafts, dust, and corrosive fumes as possible. The working surface should be covered with smooth, white glazed paper, or other material free from lint and fuzz. A good light source should be made available, as well as some means of magnifying the parts, if possible.

To remove the mechanism from the case, unscrew the three case to base mounting screws and then remove the back connection nuts from the studs projecting through the base.

If the pointer did not move from the zero mark on the scale, when the particular piece of equipment was placed in operation; then check all of the connections in the instrument proper. Before proceeding with this inspection, however, a check should have been made of the equipment itself to make certain that the defect was not elsewhere than in the instrument. If there is a broken connection or unsoldered joint, this should be repaired by resoldering, using as little flux as possible.

If the pointer shows signs of sticking at some particular section of the scale, it is possible that a small piece of foreign matter is wedged between the moving coil and the magnet. This can be dislodged with the fine steel needle, holding the mechanism in such a way as to sight through the opening between the moving coil and the iron magnet.

If the pointer shows signs of sticking or lagging over the whole scale arc, then the pivots or jewels may be worn or coated with dirt. Defective operation from this cause may be checked by noting the change in position of the pointer when the instrument is lightly tapped. If this motion is more than one division on the scale, then there is a good possibility that the pivots or jewels are in need of cleaning or repolishing.

To clean or repolish the pivot or jewel, unsolder the outside turn of the spring from the spring support by bringing the hot soldering iron against the support where the spring is soldered. Remove the jewel bearing locknut and carefully unscrew the jewel screw. Note the arrangement of the spring support and pointer stop on the pointer side of the moving coil. Also the insulating washers and spring support on the opposite jewel bearing assembly. This is necessary in order that they may be replaced properly.

The pivot and jewel screw may then be cleaned with a small, soft wood stick soaked in clean alcohol. The jewel surface can be cleaned with a pointed stick.

The steel pivot can be cleaned and slightly polished by means of a small stick applied to the pivot surface through the jewel screw opening. When cleaning the pivots, a small brass or fibre spacer should be placed between the moving coil and the iron core so that excessive pressure is not exerted on the opposite pivot and bearing.

When replacing the jewel screws and associated assemblies, make certain that the spring is neatly soldered, and that the turns of the spring do not touch each other. Adjust the clearance between the jewel screw and the pivot so that there is just a noticeable movement in the jewel when the coil is lightly moved from side to side by a slight pressure on the pointer tip. The actual distance between the pivot and the jewel surface with the movement in the horizontal position should be approximately 0.005 to 0.002 of an inch.

No attempt should be made to remove the mechanism from between the openings of the magnet as this will in general require recharging of the magnets and realignment of the whole frame assembly. Electrical continuity of the moving coil and the series resistors may be checked by connecting a small 1½ volt dry cell in series with a head set or telephone receiver and the part to be tested. A sharp click will indicate a continuous electrical circuit.

If the pointer has been thrown off balance by severe jar or overload, it may be rebalanced by sliding the small spring adjusting weights on the brass cross arms. Use a small tweezers to hold the small spring weights and slide them along the balance arms. The two arms at right angles to the pointer are for side balance. The one in line with the pointer is for tail balance.

Before placing the mechanism back on the base and in the case, make certain that all the parts are clean and free from dirt and dust particles which may lodge in the movement. When mounting the case, make certain that the small zero adjusting screw in the lower portion of the case front is in such a position as to engage the forked shaped section attached to the upper spring support.

Milliammeters and ammeters can be compared with "Good" meters by connecting the two in series. Voltmeters and kilovoltmeters can be compared with "Good" meters by connecting the two in parallel.

PRIMARY CABLES - If the primary cables prove defective, it may be only a loose lead at the place where they are soldered to the cable plug or cable receptacle. This can be remedied by resoldering, or in cases where the leads are actually broken it may be necessary to cut off a few inches of the cable and completely reterminate the cable by skinning back the wires and resoldering them in accordance with the color code on the wiring diagram. Use the old cable for a sample and do the soldering and terminations in a like manner.

CONTROL RELAYS - Figure Y, shows the interior construction of the control unit with the relays, etc. plainly marked. If the control does not operate and the difficulty is traced to the failure of a relay, it may be necessary to effect the repair of a relay or to make replacement. If the relay seems to operate, but the contacts do not make proper contact, it may be due to a burned or damaged contact of one of the relays. The contacts can be reconditioned in most cases by cleaning with a piece of fine sandpaper. (DO NOT USE EMERY CLOTH). By bending the contacts carefully they can be adjusted to make proper contact. Be sure the relays operate correctly and quitely before replacing the covers of the control.

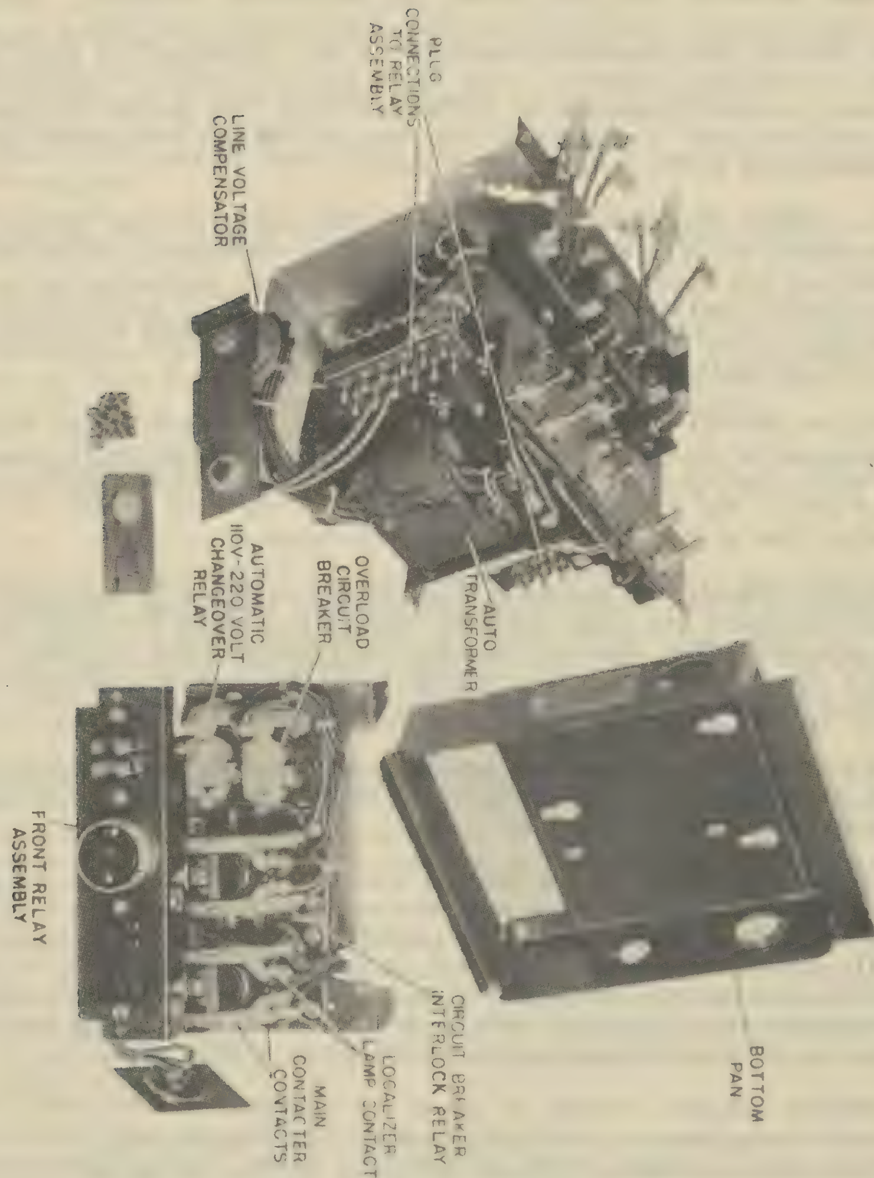
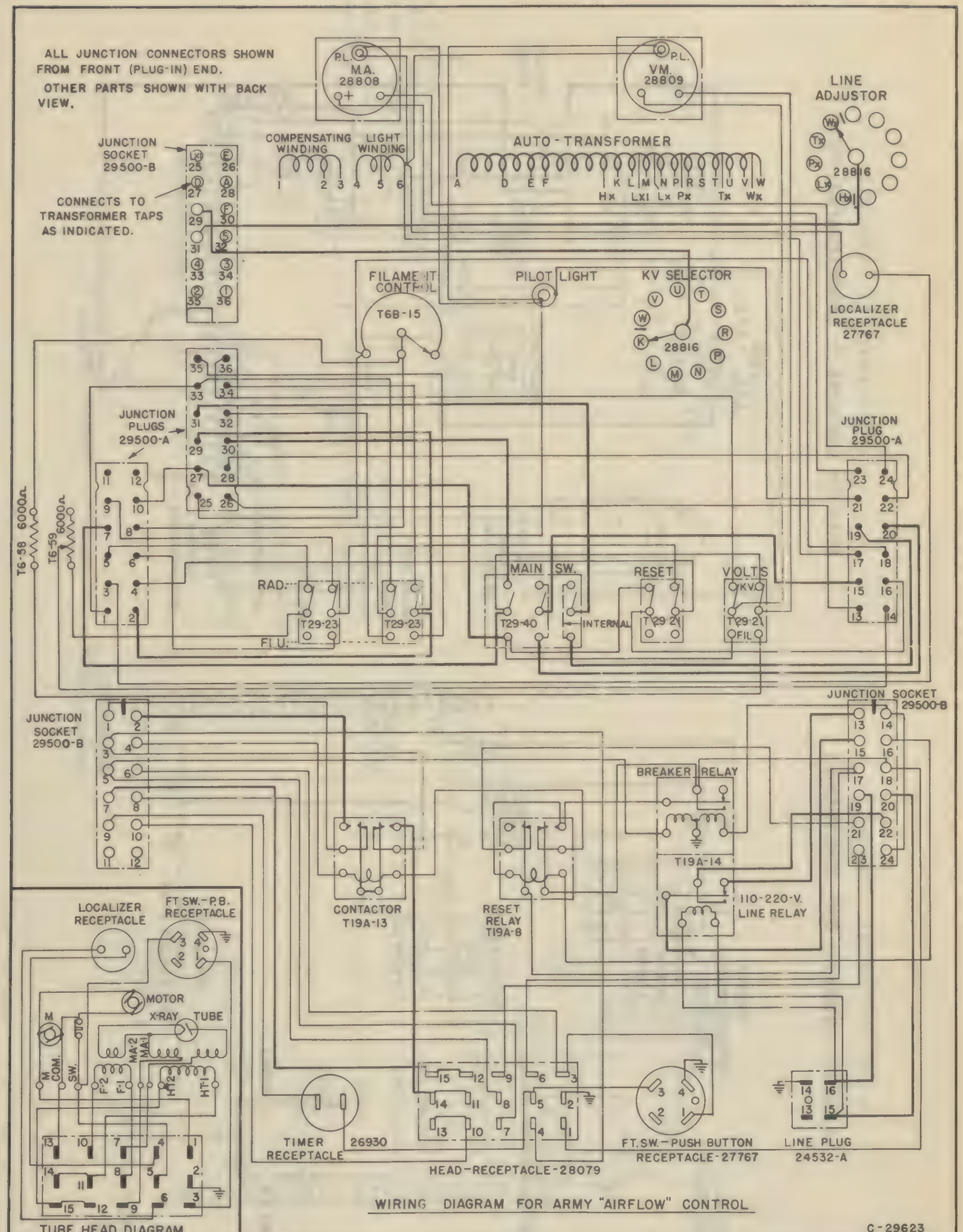
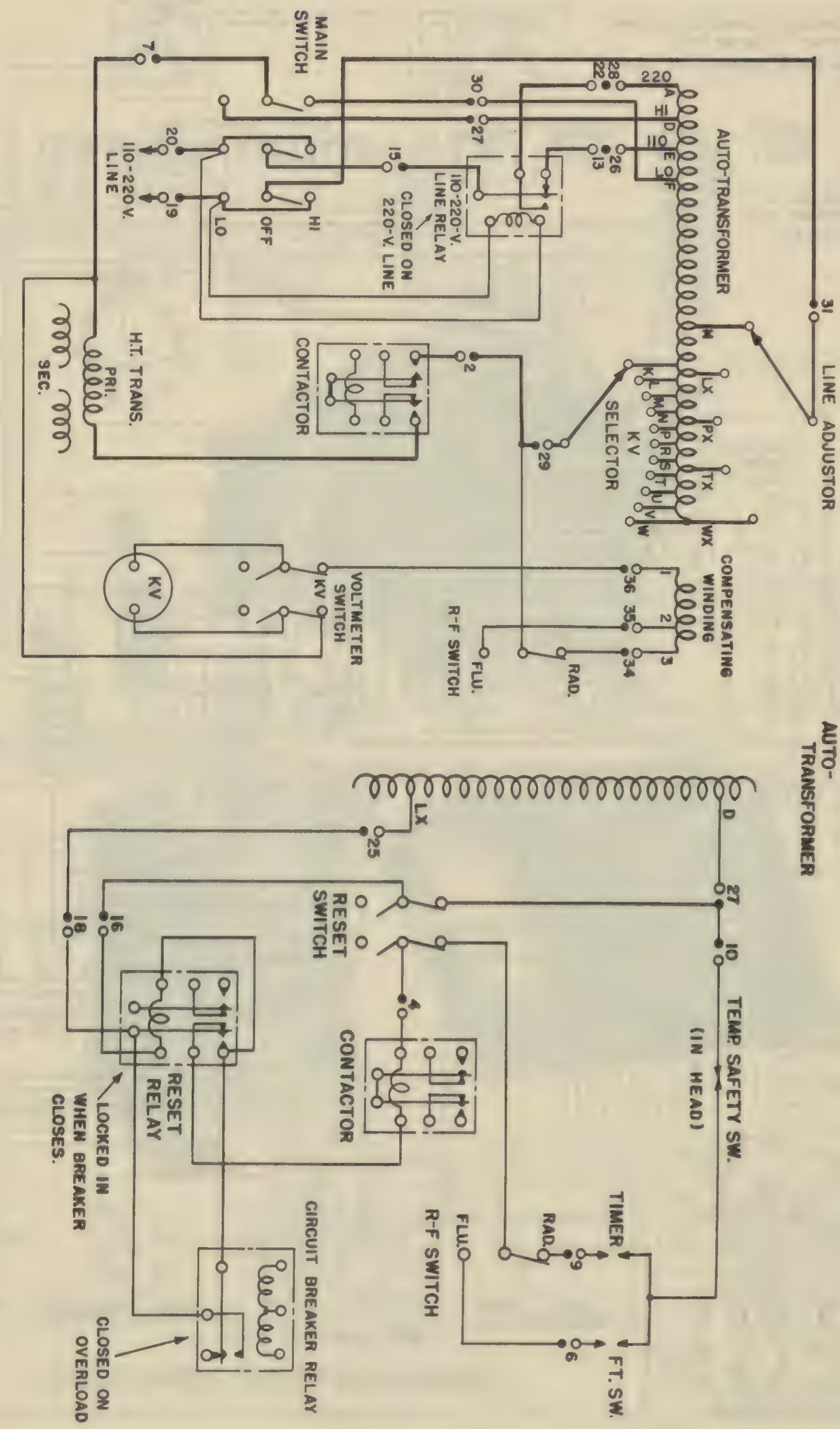

PLUG CONNECTIONS TO RELAY ASSEMBLY
LINE VOLTAGE COMPENSATOR
AUTO TRANSFORMER
OVERLOAD CIRCUIT BREAKER
AUTOMATIC 110V-220 VOLT CHANGEOVER RELAY
FRONT RELAY ASSEMBLY
BOTTOM PAN
CIRCUIT BREAKER INTERLOCK RELAY
LOCALIZER LAMP CONTACTS
MAIN CONTACTER CONTACTS

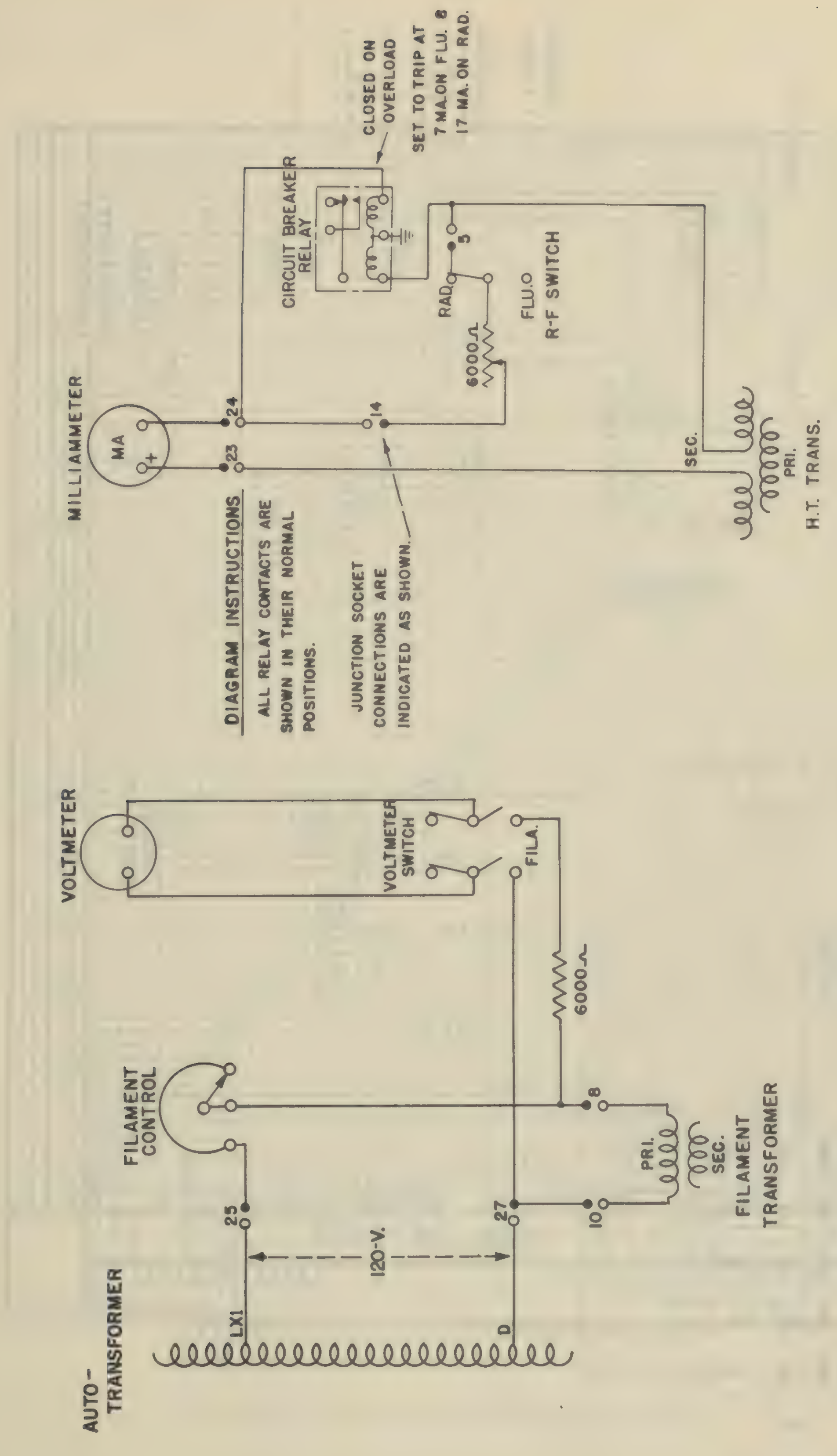
FIG. Y


ALL JUNCTION CONNECTORS SHOWN FROM FRONT (PLUG-IN) END.
OTHER PARTS SHOWN WITH BACK VIEW.
JUNCTION SOCKET 29500-B
CONNECTS TO TRANSFORMER TAPS AS INDICATED.
M.A. 28808
VM. 28809
P.L.
COMPENSATING WINDING
LIGHT WINDING
AUTO-TRANSFORMER
LINE ADJUSTOR
28816
FILAMENT CONTROL
T6B-15
PILOT LIGHT
KV SELECTOR
LOCALIZER RECEPTACLE 27767
JUNCTION PLUGS 29500-A
JUNCTION PLUG 29500-A
T6-58 6000Ω
T6-59 6000Ω
RAD.
FIL.
T29-23
MAIN SW.
T29-40
INTERNAL
RESET
T29-21
VOLTS
KV.
FIL
JUNCTION SOCKET 29500-B
BREAKER RELAY
T19A-14
110-220-V. LINE RELAY
CONTACTOR T19A-13
RESET RELAY T19A-8
LOCALIZER RECEPTACLE
FT SW.-P.B. RECEPTACLE
MOTOR
X-RAY TUBE
TUBE HEAD DIAGRAM
TIMER RECEPTACLE 26930
HEAD-RECEPTACLE-28079
FT.SW.-PUSH BUTTON RECEPTACLE-27767
LINE PLUG 24532-A
WIRING DIAGRAM FOR ARMY "AIRFLOW" CONTROL
C-29623



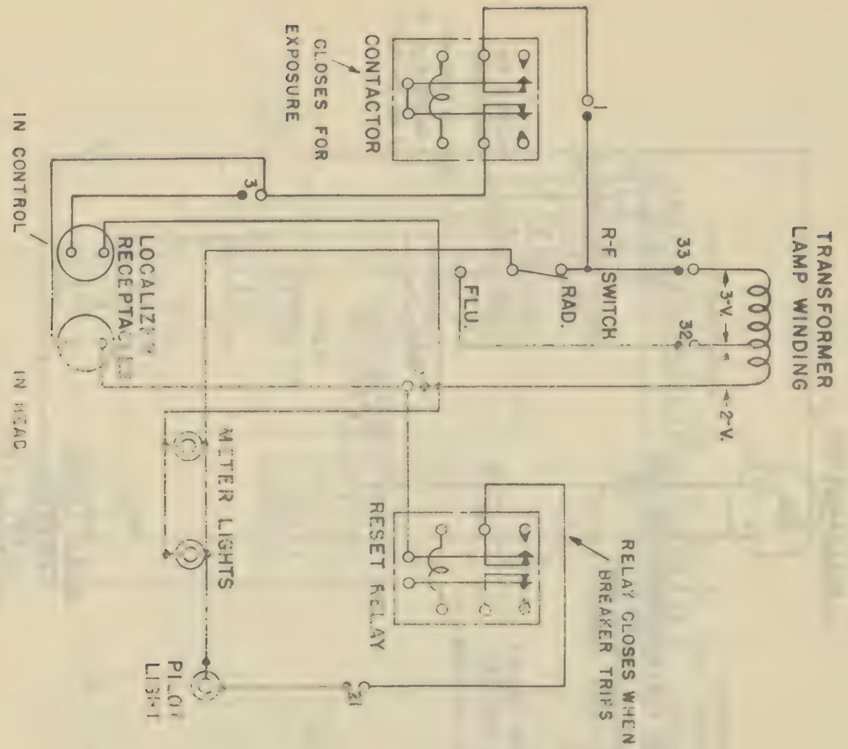
AUTO TRANSFORMER & PRIMARY CIRCUIT

CONTACTOR AND CONTROL CIRCUIT

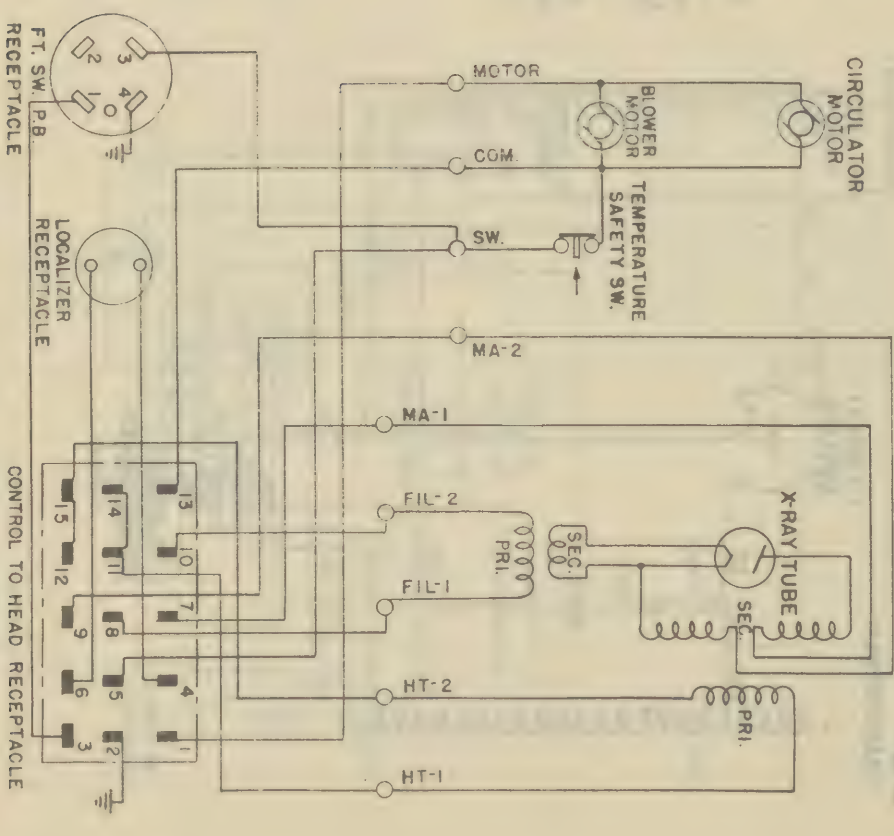


X-RAY FILAMENT CIRCUIT

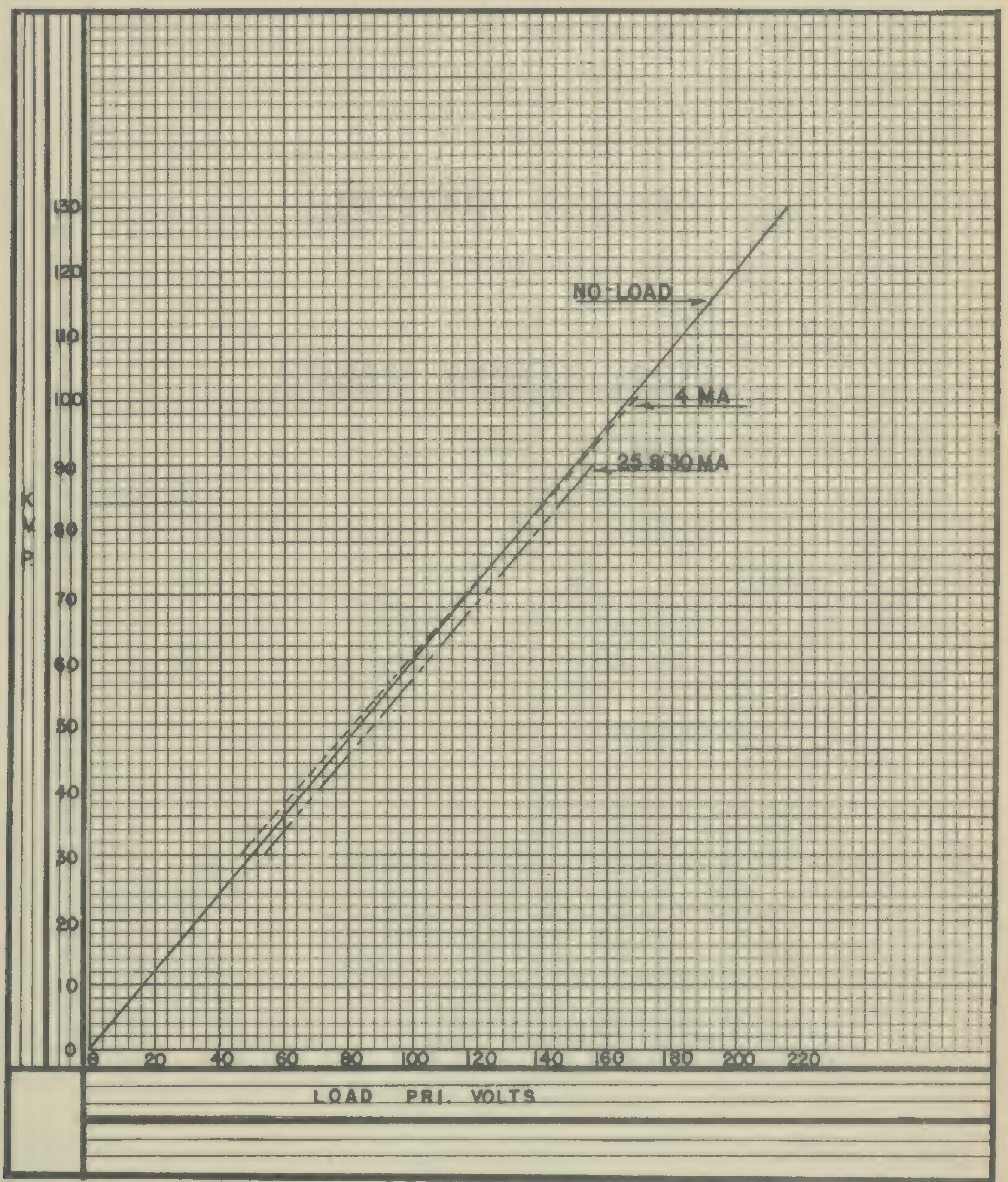
MILLIAMMETER CIRCUIT



ILLUMINATION CIRCUITS



AIRFLOW HEAD DIAGRAM


K
M
P
0
10
20
30
40
50
60
70
80
90
100
110
120
130
0
20
40
60
80
100
120
140
160
180
200
220
LOAD PRI. VOLTS
NO-LOAD
4 MA
25 & 30 MA

SECTION XXXIII

ARMY FIELD UNIT

IMPORTANT X-RAY PROTECTION - X-Ray equipment should be operated only by persons thoroughly familiar with characteristics of X-Ray radiation, and only after becoming thoroughly acquainted with the instructions contained in this manual.

It is important that everyone having anything to do with X-Ray work be fully acquainted with the recommendations of the National Bureau of Standards, and of the International Roentgen Ray Committee on X-Ray protection, and take adequate steps to insure protection against injury.

Various protective materials and devices are available. Such materials or devices should be used.

PREFACE

The original plannings and gross developments of the present design of the several U. S. Army Field Units were initiated, before the war, by the Department of Roentgenology, Army Medical School, Washington, D. C. On the basis of their constructing numerous models and testing of various arrangements, it was decided that in order to provide for adaptation of x-ray equipment for all types of medical installations in the Theatre of Operations in time of war, and at the same time for various hospital installations in time of peace, the following requirements were demanded: (1) horizontal fluoroscopy; (2) foreign body localization by means of a rapid fluoroscopic method; (3) sitting fluoroscopy, the design of the x-ray tube and screen supports providing for easy and quick shifting for the study of a patient supported to a sitting position on the litter; (4) standing fluoroscopy, to the extent of accommodating routine chest studies and also gastro-intestinal studies; (5) horizontal roentgenography, using conventional focal-film distances from 25 to 40 inches; (6) six-foot vertical chest studies; (7) six-foot horizontal chest studies, the patient lying on a litter, upon the floor; (8) ordinary bedside work in the wards, by means of mounting the component parts of the x-ray machine upon mobile chassis; and (9) superficial roentgenotherapy, to the extent of milliamperage capacities of four and kilovoltage potentials up to 100.

This versatility of adaptation has required many special developments such as improvements in capacities of the x-ray tube, improvements in the design of shockproof cable terminals and the construction of a special control. The detailed designing and developments of the x-ray machine unit and mobile chassis unit have been accomplished after considerable designing and change-over of toolings, in close coordination with Col. Martin E. Griffin of the office of the Surgeon General. Thus, these developments represent combined thinking and experience of Army men as well as of the engineers of manufacturers.

The equipment covered herein consists of several groups of specifications, so correlated in their design as to make possible the operation and assembly of one specification with another.

A combination of all of the specifications would include:

a. An x-ray tube of special design, including special shockproof cables, and automatic thermal safety cut-off.

b. A control unit designed to be simple to operate, yet extremely rugged.

c. A transformer arranged for immediate transportation without packing, with especially good electrical regulation, with a high margin of electrical safety,

and for allowable operation as high as 100 P.Kv.

d. A group of accessories for use with the transformer and control, such as:

(1) A hand timer.
(2) A footswitch.
(3) Localization lamps and cords.
(4) A variety of filters for the x-ray tube.
(5) Lead alloy aperture plates for the x-ray tube.
(6) A kit of spare service parts.
(7) A kit of tools.
(8) Gloves, goggles and apron.

e. A mobile base with tubestand on which all of the above may be mounted.
f. An x-ray table or some form of support for a litter.
g. A gasoline electric generator.
h. Special packing cases for each of above mentioned items.

The design anticipates the use of the tube, transformer, and control assembled with the mobile base as one of the possible combinations, yet it is possible to energize the table equipment without removing anything but the x-ray tube from this combination so that the mobile unit can be positioned near the table with the tube removed and installed on the table, thus serving as a combination stationary outfit or mobile unit.

The equipment is so designed that the mobile base and tubestand can be omitted. The transformer, control and tube, etc. can then be used as a stationery plant with the table. Other combinations than the above are possible.

The electrical equipment is so designed that it is only suitable for operation on 60 cycle circuits whose voltage limits lie between 100 and 130 volts, (later types will also operate from 205 to 250 volts). Whenever such source of electrical power is not available, the equipment can be operated satisfactorily from the gasoline electric generator which has been specially developed so as to have such characteristics as are essential to maintain the same electrical margin of safety as would exist if the equipment were operated from a good community line source of electrical supply.

From the above it can readily be seen that the unit can be assembled as a mobile unit in a hospital, a stationary unit in a hospital, or as a stationary unit in field work. In the latter case, it would be used with the gasoline electric generator. In the former case, this probably would not be necessary, depending upon a suitable power source.

The tube, transformer, control, and accessory group are so designed that they may be operated as low as 30 P.Kv., or as high as 100 P.Kv. With a suitable source of power, the equipment can be operated as high as 30 M.A. and 85 K.V. and still maintain low inverse voltage, due to the very good electrical regulation of the transformer and control.

The equipment can be operated at 4 M.A. 100 P.Kv. as for therapy. It can also be operated at 5 M.A. at 85 P.Kv. for fluoroscopy. Either of these operations may be as continuous as this type of work generally requires. By this is meant that in normal continuous fluoroscopy, the footswitch is not depressed all of the time. Instead, it is an "off and on" process. In therapy work, the area to be treated is changed or else the patients are changed. These rest periods prevent the tube assembly from heating to such temperature as to cause

the automatic safety shut-off to operate. In other words, treatment may be continuous up to the point that the automatic switch shuts it off. How long this takes, depends upon the temperature at the start. For example, if the temperature of the air circulating around the tube is as high as 120° F. when the exposure starts, the tube might be run without any rest period at all at 85 P.Kv. 4 M.A. for twenty-four hours. Again, if the tube were operated at 85 P.Kv. and 5 M.A. and the starting or room temperature was 100° F., the tube could be operated for approximately 50 minutes without interruption. At the end of this time, the automatic shut-off will stop the exposure for about four minutes. At the end of this interval, the tube can be again operated for approximately twelve minutes without interruption. This cycle of twelve minutes on and four minutes off can be repeated for 24 hours.

If the tube is operated at 85 P.Kv. and 5 M.A., and the starting or room temperature is 80°, the tube can be operated without interruption by the automatic safety switch for 24 hours.

These long interval ratings are based on operation at a relative humidity of 50. The use of vaseline on terminals or receptacles will permit operation at higher relative humidity and is recommended in all cases.

With the table combination most of the above operations can be performed in addition to foreign body localization.

The x-ray tube and its cables have been developed specially for this Army Field Unit. The design incorporates safety devices to prevent operation if the circulator and blower motors are not energized. It also embodies a thermal safety switch to stop operation if a predetermined temperature is exceeded. It should be pointed out that these safety devices are only intended to function in case of accident. The only way to be certain of most satisfactory x-ray tube life is to carefully observe all precautions in adjusting the milliamperage, always keeping this well within the limits stipulated throughout. In other words, no safety device can entirely take the place of good judgment.

The shockproof cables have been designed with the best possible margin of safety consistent with their flexibility and weight. These cables are arranged so as to be interchangeable, one end for the other, and one cable for the other. In other words, both cables are alike and both ends are alike. It is most important that the cathode of the x-ray tube be connected to the cathode terminal of the high tension transformer. Failure to observe this may ruin the x-ray tube. Perhaps it should be explained that if these cables were not made interchangeable to prevent this possibility, it would then be necessary to have two spare cables available where ordinarily one would suffice.

Great care has been exercised in the design to protect all cable fittings during transportation. They must be equally protected in assembling and dismantling. The cables are free to rotate both at the transformer end and at the tube end. This will help relieve strains on the cable. Nevertheless it is essential in assembly that this is not used as a means of relieving kinks or twists that may be in the cable. The cables should be straightened out first before inserting them in the tube and the transformer.

The meters of the control have plastic window covers. The window closest to pointer is shatterproof glass and will not retain a static charge. The object in using these windows is to prevent breakage which might occur with ordinary glass construction. The meters further are mounted on airfoam rubber to

absorb vibration in transportation.

One of the most important warnings that must be observed refers to the voltage of the line to which the apparatus is to be connected. One must be positive that the voltage is within the limits of the control and that the adjusting strap on the terminal board under the front cover has been properly set. The apparatus must only be connected to a 50 to 60 cycle supply line, 100 to 130 volts. (Later models also operate at 205 to 250 volts.)

This gasoline electric generator has been designed specially for this unit. It is highly important that this x-ray apparatus not be connected to any other than the type of gasoline electric generator that is intended for its operation. A warning on the top of the control clearly indicates the item number of this generator. It is equally important that this gas electric generator be kept in proper operating condition by carefully observing all of the instructions that accompany it. Be sure that it is running smoothly and steadily on both cylinders and that it is not choked with carbon, that it is properly lubricated, that the commutator and slip rings are kept clean and free from excessive oil or grease.

Much time has been spent in the design of the packing. The equipment will stand a reasonable amount of rough handling only if it is packed in the same manner as it was assembled at the factory. Study carefully the position of each part to be certain that all are returned to their original positions when packing the equipment. This is doubly important for the x-ray tube. If this is turned upside down or improperly secured, the chances of breakage are great. If this equipment is intelligently handled, it should prove to be 100% dependable, but so much depends upon its proper operation that we cannot over stress the importance of a thorough study of this entire section, for other sections of it deal more specifically with each other and every component of the entire unit--its proper assembly and packing, as well as its operation.

DESCRIPTION OF MOBILE BASE AND TUBESTAND - The mobile chassis has been specially designed to be used in conjunction with the transformer, control, and x-ray tube of the Army Field Unit. It is further designed to be dismantled and packed into a reinforced plywood chest. The complete unit incorporates all the desirable features of a mobile unit, including easy mobility, floor locks, vertical travel to allow radiography above the table and fluoroscopy beneath the table, rotation of the vertical mast through a complete circle with indices at 90° points, normal cross arm travel including a stereoscopic shift and cross travel lock; and angulation scales in two planes.

MOBILE BASE - The completely assembled unit is shown in Figure A. It will be seen that the entire unit is built up on a mobile base. The base incorporates a rectangular well, designed to receive the transformer chest. The base is provided with wheels and casters made of hard rubber material, and both are equipped with roller bearings. The caster swivel is provided with ball bearings. The two large wheels are provided with over-center locks to immobilize the complete unit. The two casters are provided with screw pin locks "1" Figure D, which engage the casters when they are thrown in parallel with the base and provides a means of securement when the base is to be packed in the chest. These rotational locks are also provided so that the wheels and casters may be locked parallel with one another when the base is to be used in conjunction with a table where it is desirable that the x-ray tube moves in a straight line, as in fluoroscopy.

The forward part of the base incorporates a bearing well which has been

machined to very close tolerances, both on the upper bearing race and the lower center bearing pivot. The degree of accuracy of this bearing determines the amount of play of the total vertical mast. The top edge of this bearing well is further

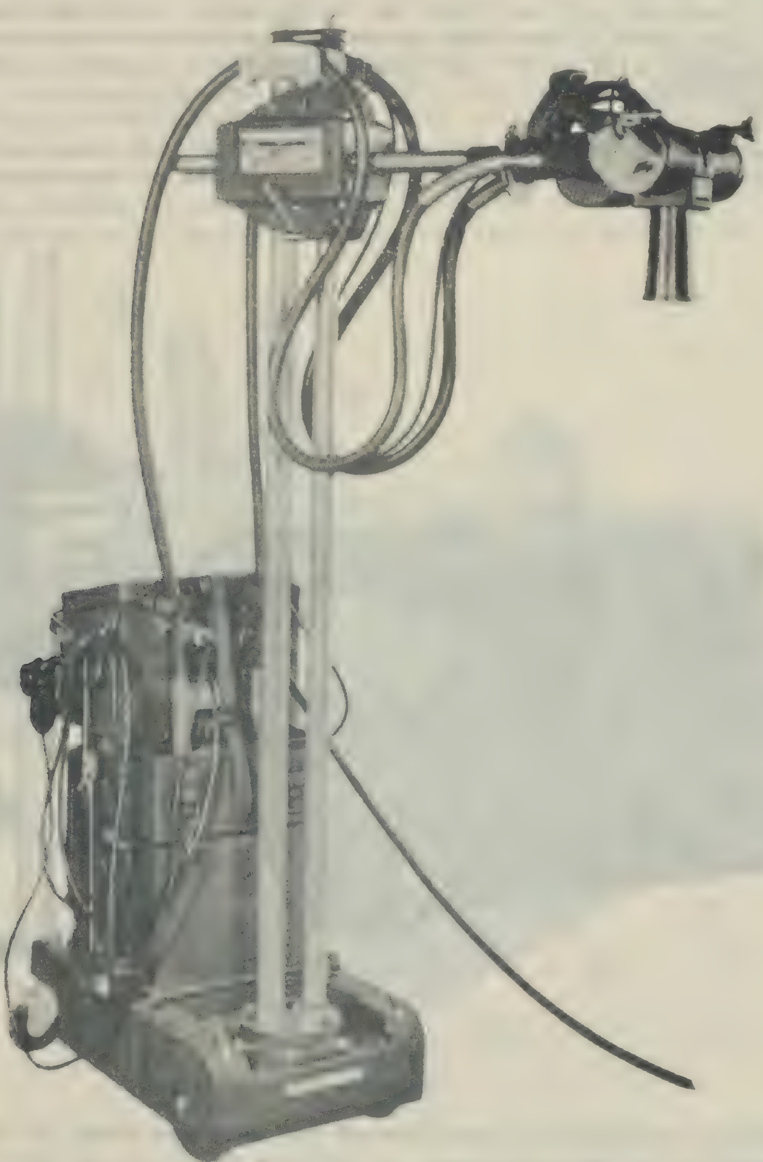


Figure A

provided with a machined face, including four indexing points to receive the ball bearing which takes the full thrust load of the mast.

The base is also provided with two lifting handles "2", Figure E, which facilitate the handling of the base when placing it in the chest. It will further

be observed that the base is provided with holes "3" for the retaining guy rods. Figure E shows these guy rods "4" in position prepared for packing into the chest, while Figure A shows the guy rod in position with one end engaged in the base and the other end engaged in the hole provided in the handle on the control. These rods have been provided to securely lock the combination of the transformer and control to the base so that they will not shift about as the unit is guided over the floor. It also makes it possible to use the handles of the control as a lifting means over a doorway sill or if the casters should be caught in some depression in the floor.

It is sometimes necessary to adjust these rods so that they will lock tightly when pulled over center. This adjustment is provided on the longer rod section

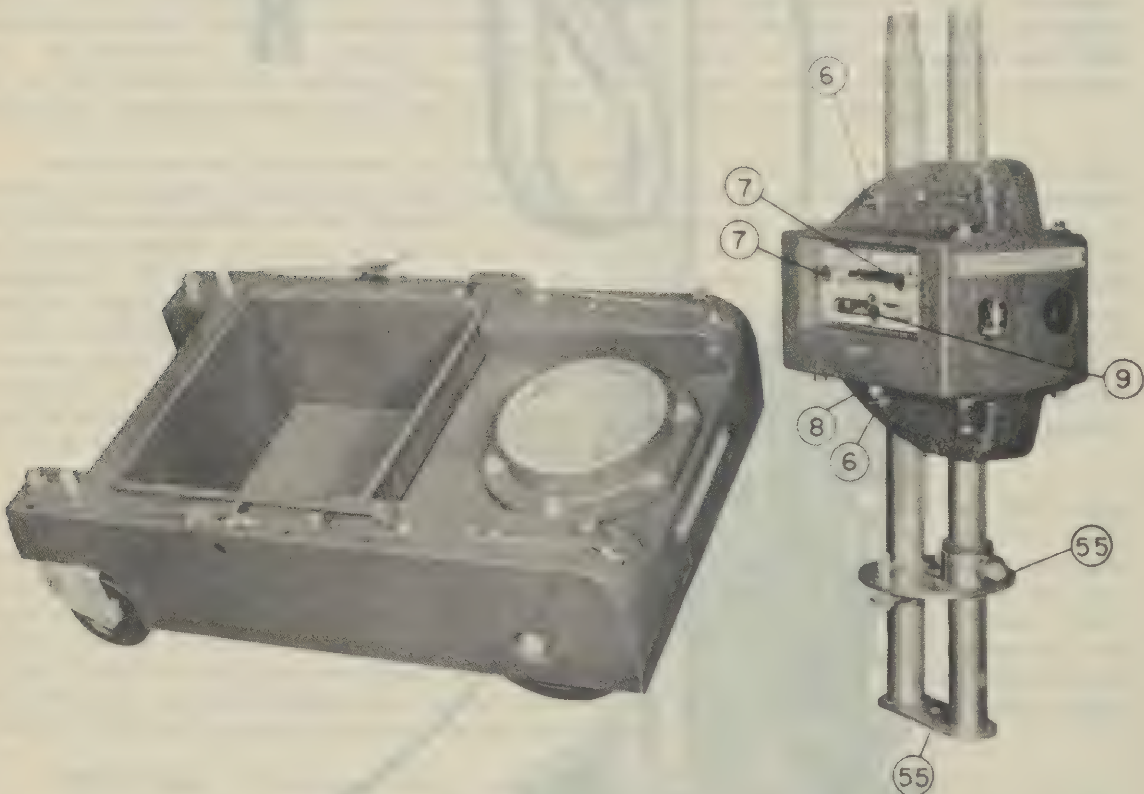


Figure C

which is threaded and locked to the body of the catch by means of a lock nut. To shorten the rod it is only necessary to release the lock nut and thread the long rod into this body section and relock the nut.

VERTICAL MAST - The vertical mast consists of three separate sections and is illustrated assembled to the base in Figure G. It consists of a lower section which includes the vertical rotation bearing, center sections of two separate pieces, and an upper section which includes a triple reinforcing plate. The interlocking part of this mast embodies the use of steel tubing machined to a very close tolerance and steel plugs machined also to a high degree of accuracy and gauged and welded in accurate duplicating fixtures so that all parts

are identical and interchangeable. To provide against twisting rotation, the separable pieces are provided with indexing pins and machined grooves which fit very closely.

Figure C shows an enlarged view of the lower section of the mast with the vertical carriage attached, and it will be observed that the vertical tubes are securely and accurately welded to the bearing plate and that a lower tie bar has also been securely welded at the extreme ends of the tubes, and that the center of this tie bar is machined to receive the lower bearing pin. Considerable research work has been done in the development of this type of bearing, and the bearing system illustrated provides the desirable features of free and easy rotation but consistent with maximum rigidity. Also as a part of this mast section an enclosed ball bearing is attached to one side which takes the vertical thrust of the mast and also provides an index by rolling into the recessed grooves of the well.

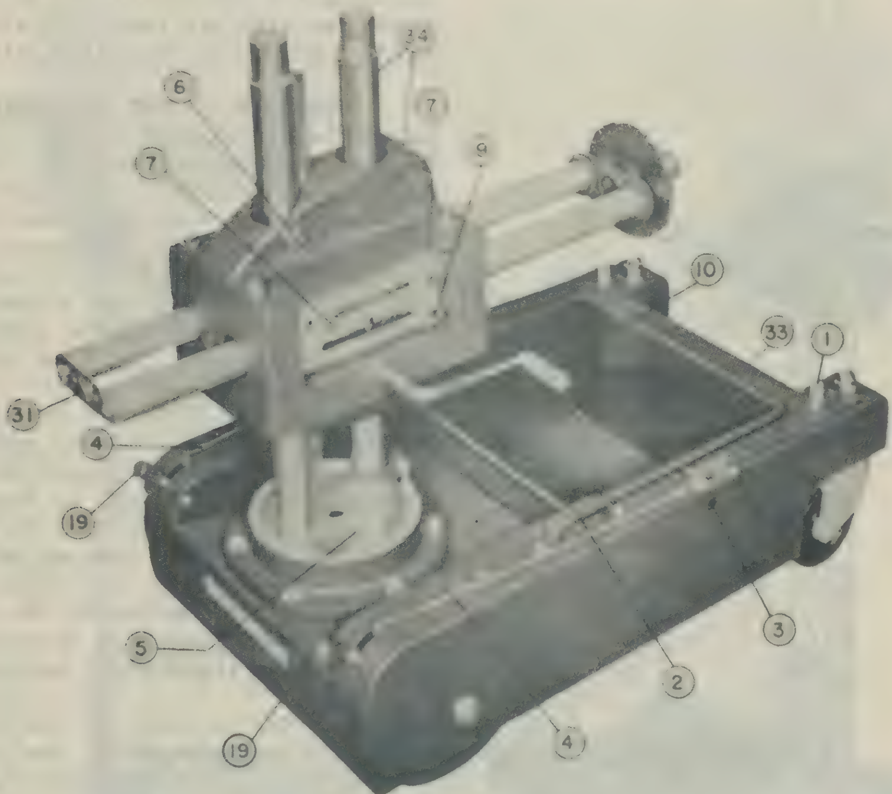


Figure E

A spring catch "5" Figure E has also been attached to the upper bearing plate with a release projecting through the top and provided with a knurled end. This catch is provided so that when the complete mast is assembled to the base and moved about it will be possible to grasp the column and lift the forward end over some obstruction, such as a door sill or the like, without disengaging the mast from the base. Obviously, the catch is released when it is desired to remove this part for packing purposes.

VERTICAL CARRIAGE - The vertical carriage shown in Figure C, affixed to the

lower section of the mast, traverses the column on two grooved bearings, and is driven by means of a crank which is geared to a rack affixed to one of the columns. Guides are provided on the rear section of the mast by means of the adjustable fibre screws "6" and "6" Figure C. The crank "10" Figure E is removable and may be inserted on either side of the carriage housing. Horizontal movement of the tube is provided by the double tubular arm , which is carried on high grade automotive ball bearings to provide ease of movement of the tube unit and associated parts. An adjustable stereoshift has been provided which is engaged by tightening the two upper knobs "7" and "7" Figure C. The lower knob "9" Figure C acts as a lock for securing the horizontal arm in position when the stem of the lock sleeve is pulled up into the notch provided.

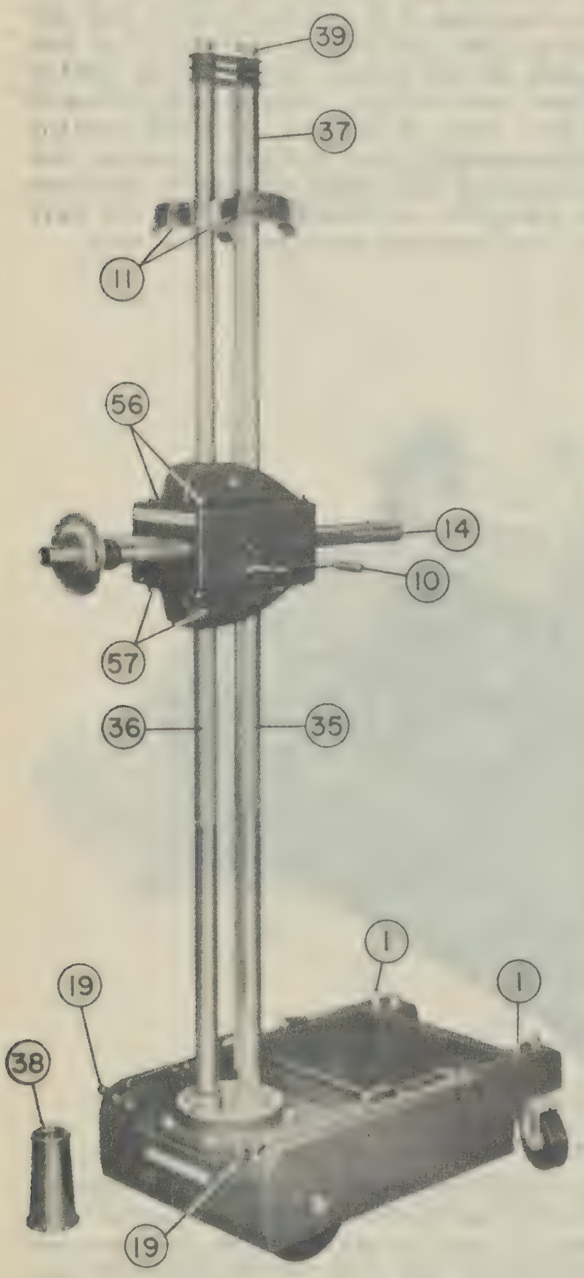


Figure G

OPERATION OF THE STEREOSHIFT - In using the stereoshift the lock knob "9" should first be loosened and the x-ray tube centered over the parts to be radiographed. With the tube in position, the lock knob "9" should now be tightened against the cross arm tube, but the stem of the lock sleeve should *not* be pulled up into the slot. However, the sleeve should be locked to the tube exactly at a point directly below this slot. Then if the shift is, for instance, three inches, each of the two knobs "7" and "7" should be set at three inches. It will be found then that the tube can be moved to and fro 1½ inches to either side of the center beam of radiation or a total of three-inch shift. The motion of the tube arm will be stopped by lugs which project down from the stereoshift locking knobs.

In order to position the tube vertically along the mast, the carriage is provided with a self-locking clutch which is released by turning the crank. Just under the crank an adjustable stud is provided with a locking nut. This stud incorporates a friction shoe which operates against the crank driving shaft with sufficient pressure to insure locking of the clutch mechanism. Adjustment of this shoe is only necessary if the vertical carriage does not maintain its position when the crank is released, and this adjustment is made by first releasing the lock nut and then inserting a screw driver in the slot of the stud and turning clockwise about one-quarter of a

turn and again locking with the lock nut. Usually this is all the adjustment that is necessary to cause the clutch to hold its position. However, the important point is to have sufficient friction at this point to cause the clutch to hold without placing an undue amount of friction against the usual cranking motion.

CABLE SUPPORTS - Figure G shows the complete vertical column assembled and the carriage positioned about two-thirds of its vertical travel. Directly above the carriage will be noted two cable supporting members "11". These cable supports engage an adjustable member "12" Figure F which slides on the upper section of the vertical mast. It will be noted that these cable supports are adjustable vertically by pressing on the rubber bumper "13" Figure F below the slide. This slide is automatically released as the carriage is driven upward, since the carriage strikes the release and the slide proceeds with the carriage. As the carriage is driven downward, the catch again comes into engagement with the rack and the cable supports are held in position.

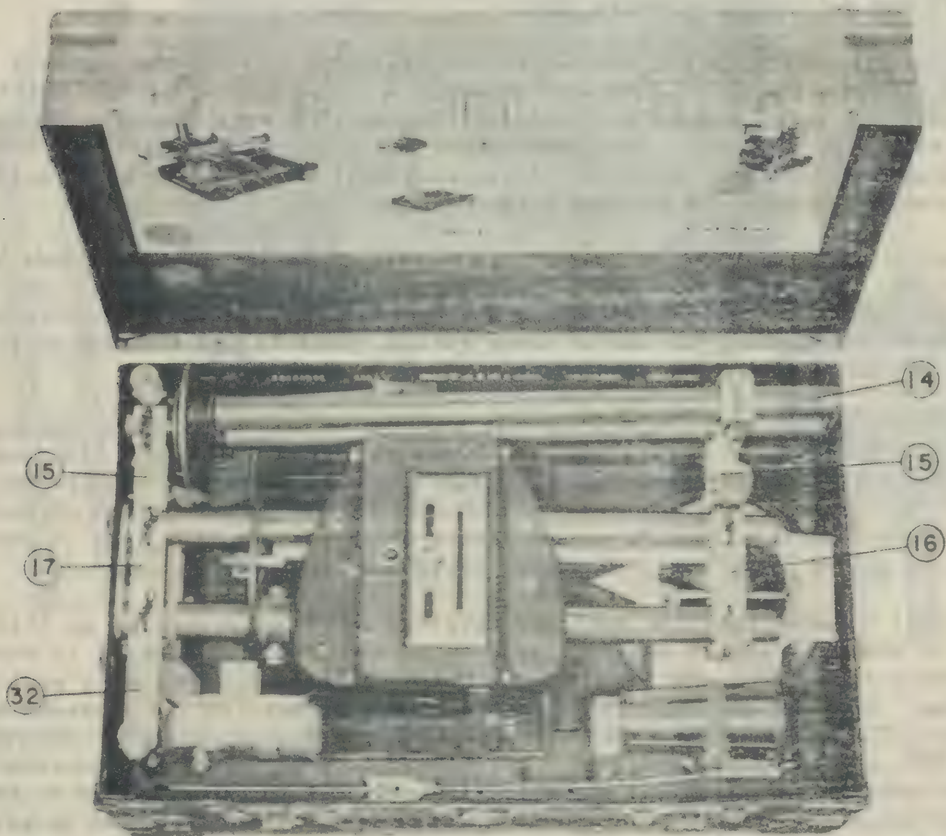


Figure B

If the x-ray tube is to be used under the table for fluoroscopy, it will first be necessary to lower the cable support so as to give the cable sufficient slack for the extreme lower position. This can easily be done by pressing on the rubber bumper below the slide, which will immediately release the catch and allow the slide to progress downward along the tubular mast. The weight of the cable and supports should be supported by one hand as the slide progresses downward, and not allowed to drop suddenly. It is well to keep these slides up as high as possible, consistent with necessary freedom of movement of the tube, so as not to

accumulate a surplus of cable on the floor.

UNPACKING AND SETTING UP OF THE MOBILE BASE AND TUBESTAND (CHEST X-1) - The mobile base chest contains the following items:

(1) The mobile base (33).
(2) Lower mast section complete with vertical carriage (34).
(3) Center plain section (36).
(4) Center rack section (35).
(5) Upper mast section complete with cable support slide (37).
(6) One pair of cable supports (11).
(7) Horizontal cross arm mechanism (Twin tube type) (14).
(8) Radiation cone (38).
(9) Crank for actuating vertical carriage (19).
(10) Two guy retaining rods (4).
(11) Two folding draw bolts (39).

Figure B illustrates the chest with the lid open, showing the complete mobile base and tubestand knocked down and packed. A large amount of engineering and design work has been done in arriving at this packing arrangement. It has been made as simple as possible, consistent with the protection of the various parts during transportation and handling. It is essentail that the operator familiarize himself thoroughly with the packing arrangement.

First, it will be seen that the complete unit packs into the main body section of the chest. It will be observed that the packing members have four heavy coil springs projecting upward, which are compressed against four steel plates secured to the top of the chest. The use of these springs prevents any shifting or knocking about of the parts during transportation.

The first operation in unpacking this unit is to remove the cross arm assembly "14", Figure B. This is accomplished by loosening the two wing nuts "15" and turning the two right angled brackets under them counter-clockwise. (These have been designed in this manner to prevent any mistakes in the proper method of packing). It will now be possible to lift up and remove the cross arm "14", and it should be temporarily placed aside until the lower section of the mast is removed.

It will be seen that the vertical carriage has been assembled on this lower section of the mast and it should always be packed in this manner. It should be particularly noted that the vertical carriage has been cranked down against the lower stop. In order to remove this section the wing nut "16" is loosened and the wing nut "17" is entirely removed. The plate under wing nut "16" is revolved through 90°, and the plate under "17" is lifted off and placed just outside of the left-hand side of the chest, as shown in Figure D. It is now possible to lift the lower section of the mast out of the chest, and this piece should also be set aside until the base is removed.

The casting "18" Figure D which holds the crank, cone, and packing brackets just referred to should next be lifted out of the well of the base and placed alongside so that the unit now appears as in Figure D. The base may now be lifted out of the chest by means of the two handles "2", and in placing it on the floor it is well to engage the two floor locks "19" which should be rotated until they point outward longitudinally from the base. It is well at the same time to release the screw caster locks "1" and "1" which maintain the casters in the proper position for packing. These are released by screwing the knurled head of the lock "1" counter-clockwise.

Next, take the lower section of the vertical mast complete with the carriage and insert the bearing end into the bearing well of the mobile chassis. This unit should not be deliberately dropped in place, but should be inserted with care so as not to damage either of the bearings. Also, this section of the carriage should be grasped at the top, that is, by means of the two projecting ends of the column. Do not attempt to lift this piece or handle it in any way by grasping the carriage, because the carriage is free to move vertically on the column and it will result in dropping of the column member and possibly cause damage to the bearing.

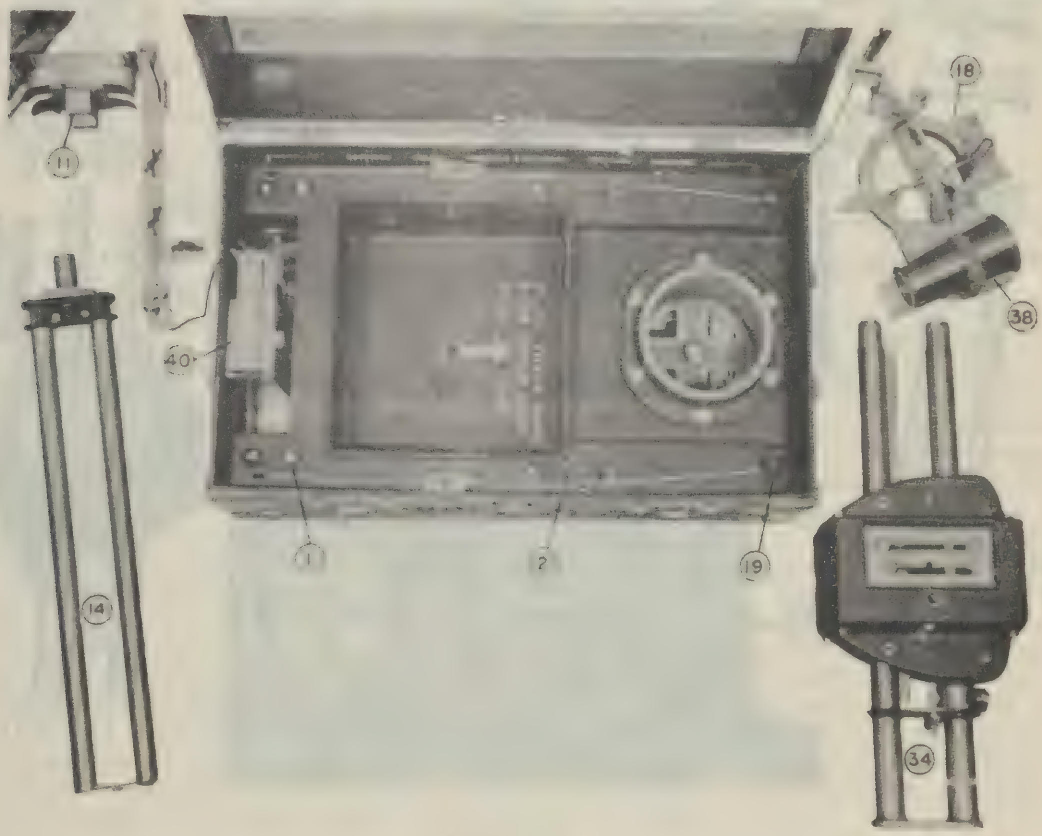


Figure D

The chest will now appear as in Figure F, and it will be seen that the mobile base rests on three hardwood blocks during transportation and that the wheels and casters do not touch the bottom of the chest. The remainder of the vertical mast and the folding draw bolts are secured to the bottom of the chest by means of two long steel straps secured by wing nuts "20" and "20". It is necessary to remove these wing nuts, but the steel straps are hinged so that they cannot be removed.

The two separate center sections of the vertical mast are now removed from the chest and joined to the base section already assembled. Obviously the center section with the rack attached should be joined to the corresponding rack section. The upper section of the mast is next joined to the parts already assembled, and the draw bolts are unfolded and inserted into the top of the mast. By turning the wing grips the threaded ends of the draw bolts will engage and they should finally be drawn up tightly. These bolts will add considerable rigidity to the entire mast assembly.

The high tension transformer should now be inserted into the well of the base, making certain that the lock side of the transformer chest is adjacent to the tube-stand. The cover of the transformer chest should now be released and folded back all the way.

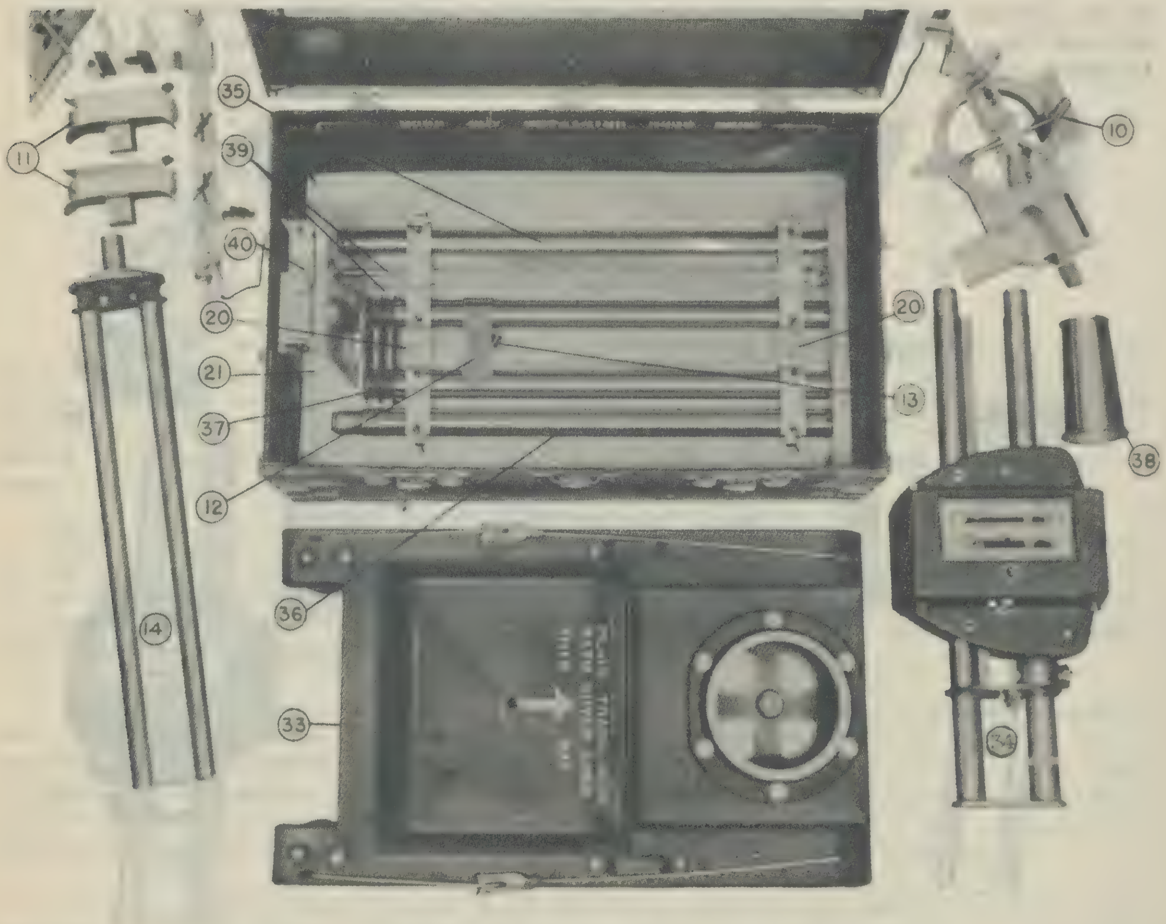


Figure F

The crank may now be removed from its packing position and inserted into the socket provided on the carriage, and the carriage cranked up to two-thirds of its travel. The horizontal tube arm should now be assembled to the carriage, and it should be emphasized that the two bars must be inserted into the proper end of the carriage. This end is identified with a nameplate "Army Field Unit". It will be observed that the horizontal tube arm is joined at the tube end by a notched steel plate into which the tubular members are welded. The other end has a removable plate "31" Figure E, supplemented by a slotted catch. This slotted catch should be turned through about 45° and it will then be possible to remove the end plate assembly. The twin tubes of this carriage should be inserted carefully and guided through the double sets of ball bearings, and special care should be taken to guide the tube through the lock sleeve. The horizontal arm should be inserted into the carriage the full distance and then the end plate should again be replaced on the end of the two projecting tubes, and the slot latch snapped back into the retainers so that the plate is held in place. The two cable supports, which are still attached to the packing members of the chest, are now removed and placed in position on the

slide provided on the top section. It is well to have this slide at eye level when attaching these supports.

SPARE PARTS - In the left hand side of the box, the packing structure incorporates a boxed section "40", Figure F, which is provided with a cover and used as a spare parts compartment. Such spare parts are included which are apt to be lost or damaged in handling or assembly.

The parts included are as follows:

1. One additional crank handle.
2. One friction adjusting stud. ("8" Figure C)
3. One friction shoe, used in conjunction with above.
4. One lock thumb nut. ("7" Figure C)
5. Three wing nuts for retaining packing brackets in chest. ("17" Figure B)

In addition to these specific parts, there is included an assortment of rubber bumpers, cap screws, nuts and lock washers used throughout the assembly and most apt to be lost or broken.

ELECTRICAL SYSTEM - The electrical system of the apparatus consists, fundamentally of a cable connecting the source of supply to the control, the control unit, supplementary control devices in the form of a footswitch and a hand timer, localization lamps energized from the control unit by means of an extension cord, a connecting cable connecting the control unit to the high tension transformer unit, the high tension transformer, and the x-ray tube unit, complete with two shockproof cables and tube motor cable.

POWER SUPPLY - All the components of the electrical apparatus have been designed to operate on 60 cycle current and a nominal voltage of 110. Line voltages in various localities will vary from 100 to 130 volts, and provision is made for accommodation of these conditions by an adjustable tap in the control unit, which will be explained later. (Later type units also operate on 205 to 250 volts.) The apparatus may also be connected to a gasoline generator which delivers 60 cycle 115 volt supply. However, considerable effort has been directed to the design of a special type of generator so that the performance will be satisfactory when connected to Army field equipment, and the apparatus must only be connected to this one specific type of gasoline generator or equal.

This generator will be known as Item 96060. This gasoline electric generator embodies either a two or four cycle, two-cylinder gasoline engine, complete with a carrying case, and the weight is approximately 200 pounds. This generator has sufficient capacity to deliver 25 M.A. at 85 P.Kv., and its electrical characteristics are such that the surge does not exceed 100 P.Kv., under these load conditions; and the inverse voltage does not exceed 95 P.Kv. when operated in conjunction with the x-ray tube, control, and transformer herein described. The wave form of this generator is such that, with the same primary voltage applied to the transformer as would be supplied on a community line, similar radiographic effects will be produced within a small percentage of variation.

RADIATION CONE - In units shipped prior to the spring of 1943, the radiation cone was packed as shown in Figure D in the casting No. 18. Since that time, a cone has also been packed in the x-ray tube chest (MDX-3), so as to be available for use with the tube when the mobile chassis was not used or was not available.

HIGH TENSION TRANSFORMER (CHEST X-2) - The high tension transformer as a unit is assembled in a seamless, drawn steel tank which is covered with a drawn steel cover into which are sealed the low tension studs and the high tension cable jackets. This whole assembly of the transformer is in turn assembled into the steel fabricated shipping chest. This chest is lined with 1/2" Celotex, on the four sides and the bottom, to prevent damage to the inner transformer tanks.

The transformer should always be shipped in the upright position, and it should likewise be stored in this manner. If the unit is laid on its side for a short period of time, very little, if any, oil will be lost from the unit, but the case should never be left in any but the upright position for prolonged periods of time.

An air breather system is incorporated in the top of the transformer to allow for expansion of the oil for normal weather conditions. If, in an emergency, the cover protecting this air breather is removed, care should be exercised so as not to damage the small spring or sealing cap and cause loss of oil during transportation.

Care should be exercised when moving or transporting the unit so that it does not receive such rough treatment as to alter the dimensions. The lower part of this chest fits into the well of the mobile base, and also the upper part of this transformer chest is designed to receive the lower part of the control unit case. Any undue distortion of this chest will obviously prevent the proper fitting of these parts.

The high tension transformer of this apparatus has been specially designed to operate in conjunction with the control unit just described and should not be operated under any other conditions. In addition to the high tension transformer itself, the tank includes a filament transformer for exciting the x-ray tube filament.

The filament transformer and high tension transformer are assembled to the top and subjected to a vacuum drying process before being assembled in the tank and immersed in oil. The oil used in the assembly of these transformers is specially dehydrated mineral oil, refined specially for this purpose. If for any reason it is necessary to add oil to a transformer, it is absolutely necessary that only this type of oil be used, or breakdown of the insulation may result.

Input terminals are provided for the excitation of the high tension primary, the filament transformer, and in addition, two studs are provided for connection of the milliammeter. These six studs are sealed into the top of the transformer and are covered with a metal protective cover. A six lead cable is attached to these studs and in turn connected to a six pole plug which plugs directly into the rear of the control cabinet, thus allowing for rapid erection and connection of the unit. In the case of an emergency where this plug may be damaged or its receptacle damaged in some way, it is possible to connect directly from the studs on the top of the transformer to the studs in the control cabinet which are marked correspondingly.

In addition to the low tension studs, two cable jackets are provided for entry of the shockproof, high voltage cables. It should be specifically noted that these jackets are marked "Anode" and "Cathode" respectively, as is the x-ray tube, and when connecting the shockproof cable between these two units the "cathode" of the transformer must be connected to the "cathode" of the x-ray tube. All shockproof cables are identical, but the connection of cathode to cathode and

anode to anode must be maintained.

As a protective measure against possible accumulation of foreign matter in these jackets, cork plugs are provided to seal them off when the cables are not plugged in. Likewise, to prevent damage to the low tension connecting plug, a small clip is provided to fasten it inside of the top of the chest during transportation.

These cable jackets are moulded from special high dielectric plastic compound which may be easily broken by rough handling. Care must be taken to prevent breaking these insulators by striking them with any hard object. A reinforcing member of tough paper base bakelite has been pressed over the exposed part of the moulded insulator to give it maximum strength and to avoid breakage.

It will be noted that the inside of the upper compartment of the transformer chest is provided with two tapered guides which receive the extended bottom of the control unit and properly align it on assembly.

The cover for this transformer chest employs a double acting hinge which allows the cover to fold down flush with the side and which exposes a hook onto which the main line cable may be coiled when the unit is set up as a mobile apparatus. The cover is lined with a felt gasket so as to make the complete assembly weatherproof for transportation purposes. Steel handles have been provided to facilitate assembly and transportation of the chest.

X-RAY TUBE UNIT (CHEST X-3) - The x-ray tube unit has been specially developed for use with this equipment. It will withstand prolonged operation for normal fluoroscopic and therapeutic work within the rating. The x-ray tube insert is suspended on the cable entry bushings in the concentric metal cylinder of its housing, and the housing is filled and sealed with specially processed insulating oil and every precaution and measure is taken to prevent contamination of this oil. The inside of the housing is specially treated with high temperature varnish. All metallic parts have been nickel plated. Ray-proofing is accomplished with a moulded plastic which is chemically inert. This ray-proofing cylinder incorporates a lead salt, which in addition to serving as ray protection acts as a dielectric shield. The x-ray beam leaves the housing through a recessed plastic port, which is also made of special material which does not deteriorate rapidly in the presence of x-rays. The port is recessed so that a minimum amount of oil is interposed between the glass of the x-ray tube insert, thereby reducing the inherent filtration of the unit to a minimum.

In order to insure rapid dispersion of the heat generated in the anode stem, the tube unit is equipped with an internal impeller, driven by a specially processed motor. The oil stream is directed along the entire longitudinal inner face of the housing cylinder, and thus the heat is positively distributed to the housing rapidly.

As the temperature of the oil increases, its volume necessarily increases in a proportionate manner, and since the unit is sealed off to the atmosphere a metallic bellows is incorporated at one end of the housing, which compensates for the extremes of volumetric changes of the oil. As a safety measure, a specially designed safety switch and visible signal button has been incorporated in the bellows design so that as the bellows expansion reaches its limit the button starts to project and exposes a red section of its length, indicating to the operator that the unit is approaching its total heat capacity. If operation is continued beyond this point and more heat is generated than the unit will allow, the safety switch

incorporated, trips and opens the main contactor circuit. It will remain open until the unit has cooled down to the point of again allowing a definite operating period, the differential of time between opening and reset closing of the switch being governed by the over-center mechanical action of the switch incorporated in the bellows assembly. For instance, if a low milliamperage value, such as 4 or 5 is being used, and it accidentally becomes a milliampere or two higher so that 6 or 7 M.A. is flowing through the tube instead of 5, then the gradual heating of the oil will cause the expansion chamber to move outward and the red signal will show, and, if this is ignored or not observed, the automatic electric cut-off will function.

It should be emphasized however, that this safety switch is provided to protect the x-ray tube when used for fluoroscopic and therapeutic work, and prevent possible overheating of the tube unit.

For the higher current techniques used in radiography, however, the heat generated at the target is not transferred rapidly enough to actuate this safety switch, and if excessively high milliamperages are used the target of the tube may be melted before there is much increase in the temperature of the oil and therefore the limits of exposure as prescribed on the control panel must be carefully observed.

It should be noted that the nameplate on the tube is inscribed with the words "Cathode" and "Anode" and arrows pointing to the respective cable jackets, and when the cables are plugged into the tube, precaution must be taken so that the cable in the anode side plugs into the transformer jacket which is also marked "Anode". Failure to observe this precaution may result in damage to the x-ray tube.

The x-ray tube housing is provided with a small blower and associated housing mounted between the cable entry bushings. This blower housing is in turn connected with a cylindrical enclosing shield to guide the air stream over the entire housing and thus facilitate dissipation of the heat which has been transferred from the anode to the housing by the impeller. Two receptacles have been provided in this housing, one for the connection of the thermal switch and the other as the means of transferring the action of the safety switch back to the control, and also to furnish current to both the impeller and blower motors. As has been explained previously, if the thermal overload switch functions, it opens the main operating relay in the control. As an additional safety feature the tube motor circuit has been provided with a safety relay mounted in the control unit, which operates by passage of current to the motors. If the plug which supplies current to the motors is inadvertently left off or accidentally disconnected, the circuit furnishing current to the main operating relay is automatically interrupted and held open until this plug is again attached.

With the introduction of the steel tube housing, the temperature switch cord and its plug and companion receptacle have been eliminated and the connection of the Thermal switch has been made inside the housing.

The tube is also provided with a flexible measuring tape to indicate distance from the focal spot to the patient. Care should be exercised when using this tape so that it is returned to the housing and not left dangling, and at all times precaution should be taken so as not to bend the steel tape at a sharp angle since it is fabricated of spring steel and it can easily be broken if bent too sharply.

MOUNTING HANGER - The x-ray tube unit equipped with a mounting hanger "2" Figure H made of malleable iron and machined to be readily adaptable to the table

or horizontal cross arm of the tubestand. It will be observed that the hanger is equipped with two end rings. One end ring employs a locking clamp and knob, while the other end employs a clamp with a draw bolt to maintain a given amount of friction against turning of the head in the hanger. The end of the tube which is equipped with the knob lock, has an angulating scale indicating the degrees of rotation of the tube about its axis. The center bearing of the hanger is equipped with a locking clamp and wing screw which acts as a retaining clamp when partially released and as a lock against rotation when drawn down tightly. This clamp also employs a notched center section which acts as an indicator against the entire tube head about a horizontal axis.

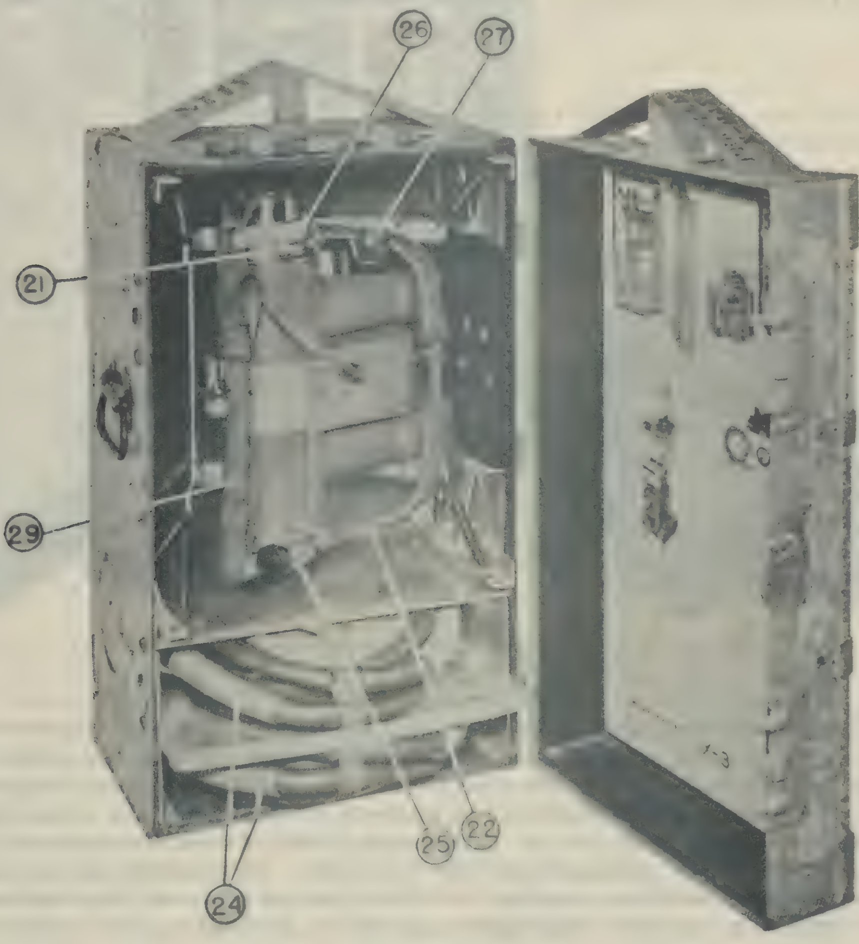


Figure H

FILTERS AND APERTURE PLATES ("23" Figure J) - The x-ray tube is supplied with a built-in filter slide which will accommodate up to 3 mm. of filter. The filters are held in position by means of an indexing spring clip which engages a notch in the side of the filter. The lead alloy aperture plates are engaged in like manner. As a precautionary measure against possible burns, the x-ray tube unit is equipped with a permanent .25 mm. aluminum filter secured to the housing proper, which cannot be removed without dismantling the filter slide.

In addition to the two lead aperture plates which must be perforated by the user according to his needs, three lead apertures are included which have already

been perforated which can be used in place of the usual radiographic cone especially for small areas. These three plates are stenciled to indicate the field coverage at 30 inches. It is very desirable to utilize these plates to avoid the use of excessive scattered radiation, which would be present in a large field coverage when only a small area needs to be radiographed.

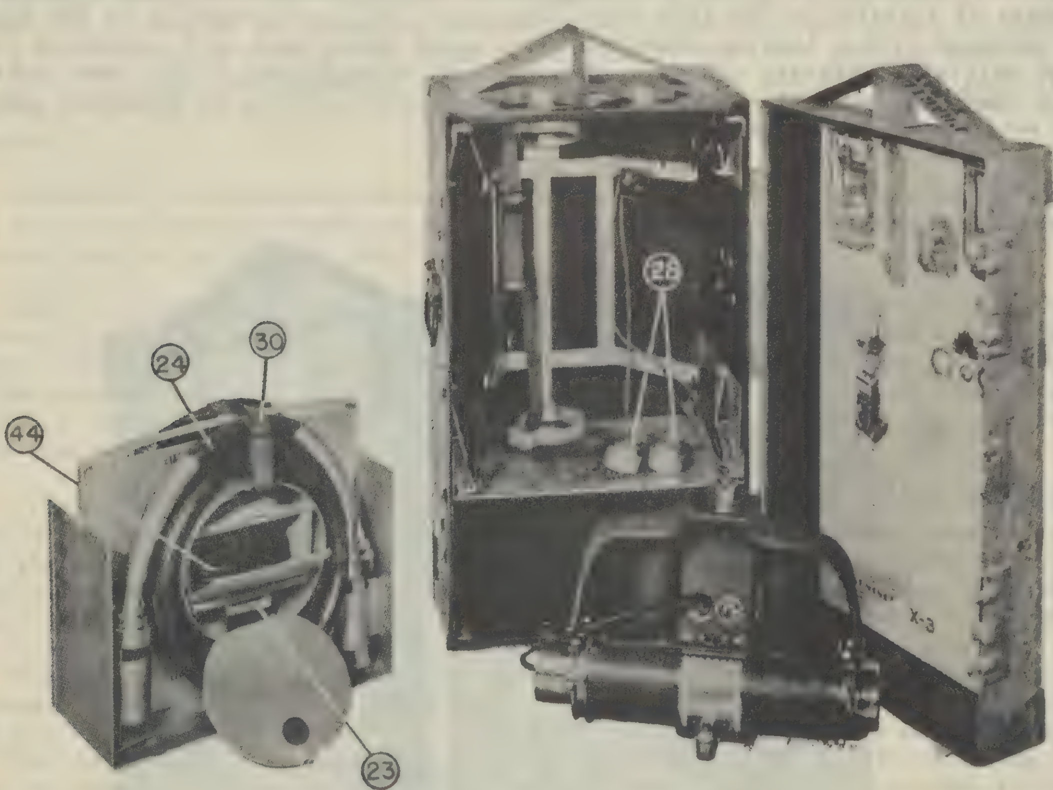


Figure J

SHOCKPROOF CABLES ("24" FIGURE J) - In order to supply high-tension and filament current to the tube housing, two shockproof cables are provided which plug into the entry bushings of the housing. These bushings are of special design to prevent oil leakage. The contacting members of the plug are concentric so as to allow rotation of the plug in the jacket and thus relieve the cable of any mechanical strain during the manipulation of the tube. Concentric construction also gives the maximum of surface contact in the limited area of the cable end, and in order to keep the contact resistance as low as possible, all contacting parts are silver-plated.

To facilitate assembly both cables are of identical construction, and in addition both ends of each cable are identical. The general design of the cable provides the necessary inner conductors to carry the high-voltage and the current for the x-ray tube filament. The cable then has an outer metallic sheath which is properly insulated in relation to the inner conductors so as to withstand the high-voltage. This metallic sheath, which is grounded, is in turn covered with a heavily lacquered woven cotton braid to make the entire cable weatherproof and to prevent any abrasion of the ground sheath. The assembly is then in turn protected at either end with the flexible metal tubing to prevent damage to the cable and also to prevent sharp bends. During operation the cable should never be bent on a radius of less than six inches.

PACKING OF THE X-RAY TUBE UNIT (CHEST X-3) - The x-ray tube chest contains the following:

1. The x-ray tube unit complete with hanger.
2. Two shockproof cables (24).
3. One tube motor cable.
4. One set of aluminum filters (23) consisting of:
   One 1/4 mm. aluminum filter.
   One 1/2 mm. aluminum filter.
   Three 1 mm. aluminum filters.
5. Five lead alloy aperture plates, (two blank and three perforated).
6. One two-ounce tube of pure white vaseline.
7. Cone.

It should be emphasized that this chest must always be transported in the upright position. The top of this chest is indicated by the steel peaks. However, the chest may be stored in any other position and it is only necessary to keep upright during transportation.

The x-ray tube is suspended in the chest with coil springs so as to take shock in any direction. It will be observed that the springs in the upper part of the chest are heavier than the remainder of the springs. These heavy springs sustain the load of the tube and cradle during transportation. The springs are attached to angle irons which are anchored to the case by riveting, and are also supported from twisting by means of the reinforcing plate and welded angle corners.

Figure H shows this chest opened up with cables and tube in position. The x-ray tube is supported in the spring mounted cradle by means of two-ring shaped sections "25" and "26" at either end of the tube and a small cradle "27" which the tube hanger engages. These ring-shaped sections are bound with rawhide to protect the finish of the tube. The upper ring is provided with a hinge and spring so that the tube can be released from its mounting.

In order to remove the tube from the shipping chest the two cable jacket plugs should first be removed ("28" Figure J) and then release the braided strap "29" from the buckle, whence a slight pressure on the upper ring will release it from the upper end of the tube. The tube will still hang in the lower ring and be supported by the small cradle which engages the hanger. With the strap entirely free, the tube may be grasped at the upper end (which is now free) with the left hand, and then by grasping the other end of the hanger with the right hand and lifting upward the tubewill be released from its mounting. It should be noted when the tube is withdrawn that the hanger is locked to the tube housing in the extreme angulated position where the blower housing of the tube nearly touches the back section of the yoke. It is important that the hanger and tube housing be locked together in this position before attempting to repack the unit in the chest. The cord which passes into the end of the tube for the safety switch will find sufficient clearance in the offset section of the top ring to which the braided strap is secured. The ring fits the end of the tube snugly and the cord should always be placed in the position of the offset in order to prevent pinching the cord between the ring and the end section of the tube. With the introduction of the steel tube this safety switch cord has been incorporated within the housing. Also, when reassembling the unit for transportation it is quite important that the teeth of the buckle engage the strap tightly, and to this end the buckle is provided with a rectangular eye at the top through which the tip of the strap and the surplus should be pulled tightly before knotting the surplus around the permanently secured section of the strap. Failure to do this may result in loosening of the buckle and the release

of the tube from its spring mounting, and consequent damage or breakage.

These cable jackets are moulded from special high dielectric phenolic compound which may be easily broken by rough handling. Care must be taken to prevent breaking these insulators by striking them with any hard object.

ASSEMBLING TUBE TO STAND - *CAUTION:* WHEN ASSEMBLING THE X-RAY TUBE ON THE MOBILE UNIT, IT IS EXTREMELY IMPORTANT THAT THE HIGH TENSION TRANSFORMER BE IN THE WELL OF THE BASE, AND LIKEWISE WHEN DISMANTLING THE UNIT, THE X-RAY TUBE SHOULD BE TAKEN OFF FIRST. This procedure must be followed since the unit will be top-heavy and tend to upset without the stabilizing weight of the transformer.

Figure J shows the tube out of its mounting with the upper ring sprung up to allow entry of the tube. After the tube is removed from the chest it should be assembled to the stand or table as required. Before attempting this assembly, however, it is well to make certain that the clamp and wing screw provided for attachment is sufficiently loosened so as to allow the clamp to pass over the tapered ring which is a part of the mounting on the table and tube stand. All that is necessary then is to lift the tube and hanger so that the mounting bearing of the hanger lines up with the projecting part of the horizontal tube arm of the mobile unit or the equivalent part on the table and push on and rotate until it is completely engaged. The screw should now be pulled down, which will cause the clamp to pull down over the tapered bearing ring and hold it in position.

PACKING OF SHOCKPROOF CABLES - Figure H also shows the shockproof cable drawer in position, and Figure J shows the cable drawer withdrawn with the compartment open.

It is very important that the cables always be returned to this drawer and assembled in the proper manner when they are not plugged into the tube and the transformer.

The terminals on the end of the cable are fabricated from high dielectric material and as such must be handled carefully. In addition to this, the terminals of the cable must be kept clean and should therefore not be left in a position where they are able to accumulate dirt or moisture. It is advisable to wipe these terminal parts off very carefully before inserting them so as to remove any moisture left from the hands. Under conditions of extreme humidity, and especially in operation in cold climates, extreme care should be exercised in connection with the cable terminals and their receptacles in the shockproof tube and in the high tension transformer. For instance, if an x-ray tube or transformer is taken from a cold place to one in which the temperature is higher, condensation will necessarily occur. This will also occur on the terminals and in the terminal receptacles. This could cause failure of these parts so it would be advisable to leave them exposed until they have gradually reached the temperature of the location in which they are to work. Then carefully wipe them dry. After thoroughly cleaning and drying these terminals of the cables and the inside of the receptacles of both the transformers and the x-ray tube, do not touch or handle these parts with the hands. It is recommended that a liberal coating of vaseline be applied to the cable terminals by means of a clean stick or cloth before inserting them in their receptacles.

The shipping drawer, as will be observed, consists of a metal frame with a center shelf, and a steel cylinder is welded into this center shelf, which acts as a short drum keeping the cables in the proper position for transportation. The center of the hollow cylinder acts as a compartment for storage of the tube motors

cable, and also for the filters and lead alloy aperture plates.

The ends of the cables are protected with caps incorporating a threaded bushing which engage the spun cable caps which normally thread onto the shockproof housing. These protective caps are fastened to the drawer by a short section of cord to prevent loss. As can be seen in Figure J, the cables are bound to the cylinder by means of a strap "30" which is riveted to the cylinder.

In order to remove the cables from the drawer, they should be laid flat with the cylindrical compartment door up, since this will allow the strap to be released from the buckle. The cable ends should now be removed from their sockets, and it will be observed that the cable protectors may be pulled out with the cable ends to the limit of the cord length. The protective caps should now be unscrewed from the end of the cable by holding the chrome retaining cap in one hand and screwing off the protector with the other. Then by grasping the coiled cable with both hands it may be lifted off the drum. Caution should be exercised if the cable is now laid down because it has a tendency to uncoil and, if it is placed on a table or surface where it will fall, the terminal may be broken. Therefore it is usually best to plug the cable directly into the transformer. The other cable should be removed in the same manner and plugged into the transformer.

It is important that whenever the cables are removed from the drum and assembled to the transformer and tube that they be fully uncoiled and straightened before either end is plugged in, or at least when one end is plugged into the transformer and secured, the remainder of the cable should be first straightened out before attempting to assemble the other end to the tube. This will prevent any unnatural twists or kinks in the cable.

When replacing the cables back on the drawer, the reverse procedure should be used. In other words, the drawer should be turned with the compartment lid down and the two protectors pulled out and laid alongside. The cable should be formed in a coil of 3½ turns, placing it over the drum and threading on the protective caps individually, and then pushing the cap into the socket of the drawer. The strap should be pulled around the cable which is now on the drum and threaded under the handle, and the complete drawer with one assembled cable now turned over and the process repeated for the remaining cable. The strap may now be pulled through the buckle and tightened. The tube motor cable is coiled up and placed in its compartment, and likewise the cone filters and aperture plates can be replaced, the door snapped shut, and the complete drawer returned to the chest. It is usually best to reinsert the tube cable drawer in its compartment with the chest setting flat so that the drawer is dropped down vertically into the chest, rather than attempting to slide the drawer in horizontally with the chest upright.

This cable drawer should always be placed in the chest with the compartment door end adjacent to the inside or nearest to the x-ray tube compartment and not with the compartment door down.

CONTROL UNIT - The control unit acts as a central means of controlling and adjusting the voltage applied to the primary of the high-voltage transformer, and a means of regulating the filament current of the x-ray tube to control the milliamperage. It also acts as a central point for the connection of the various cables for connecting the line and the accessories.

The top of the control unit has an etched nameplate which embodies various cautions and instructions which must be strictly adhered to. It will also be seen that the various elements of the control are lettered alphabetically. This method

has been used both to identify the various controls and is also the operating sequence. This will be explained under the section referring to "Operation of the Unit".

The top of the control as shown in Figure K embodies the following operating components:

"MAIN" SWITCH "A" - The "main" switch "A" serves to open and close both sides of the main line circuit to the autotransformer, and serves to energize the control. When the main switch is turned on:
The kilovolt meter should indicate;
The pilot lights in the meters as well as the red light between the meters should light;
The x-ray filament should light;
The x-ray tube blower should operate;
The localizer lamps should light.

"RADIOGRAPHIC-FLUOROSCOPIC" SAFETY SWITCH "B" - The switch "B" is referred to as a radiographic-fluoroscopic switch. When the switch is set to the fluoroscopic side, one deck of the switch selects the foot switch, and disconnects the hand timer, the second deck selects the low scale (K) of the milliammeter, and disconnects the high scale, and the third deck selects the limiting resistor for the filament circuit of the x-ray tube. When the switch is set to the radiographic side, the first deck of the switch selects the hand timer and disconnects the foot switch, the second deck selects the high (K) scale of the milliammeter, and disconnects the low scale, and the third deck shunts out the limiting resistor. It should be noted that the radiographic position of this switch is marked with a red dot, indicating caution in operation,,and caution should be exercised, since on this setting it is possible to operate the tube at 30 M.A. by means of the timer, and if this capacity is exceeded, it may result in overloading the x-ray tube and possibly cause failure.

"KILOVOLTS" SELECTOR SWITCHES "C" AND "D" - The operating knobs "C" and "D" are kilovoltage selectors, major and minor, and it is possible to select any kilovoltage between 30 and 100 P.Kv. in increments of less than 1 Kv. per step, and this kilovoltage will be indicated on the voltmeter directly above the operating knob. It should be emphasized that these kilovoltage selectors must NEVER BE ROTATED during an exposure, since this may cause serious damage to the switch members. It will be observed that buttons 8, 9, and 10 are identified with a red dot, indicating that caution must be exercised in using these steps and reference should be made to the kilovolt meter before making an exposure.

"KILOVOLTS" METER "E" - Scale "E" of the voltmeter shows the kilovoltage applied to the x-ray tube under load. It should be emphasized in connection with this kilovoltage scale that the meter indicates the kilovoltage applied to the x-ray tube with the current passing through the tube, and if a presetting of this is desired, it will be necessary to determine what drop in meter reading is developed for each setting of milliamperage used. It is not possible to precalibrate this instrument because it may be operated on different types of service, each of which will require individual calibration.

It should be noted that while all the illustrations show rectangular meters, it has been necessary on some machines to substitute round meters because of the restricted production capacity of the meter industry. The round instrument has the full approval of the Surgeon General's office and it is identical in electrical characteristics to the square instrument.

"CHECK FILAMENT" SWITCH "F" - Toggle switch "F" is a momentary contact switch which is normally held in the kilovolts position by spring pressure, but in order to check a filament setting, it is necessary to throw this switch upward to the "check filament" position, and the upper scale of the voltmeter marked "G" becomes active. The presetting of filament current for a given milliamperage will vary from one x-ray tube to another, and likewise from one supply line to another, and therefore it will be necessary to chart the particular tube which is set up with the unit for the particular line on which it is being operated. An example of this type of chart is shown on the front of the control unit. The selection of filament current should be done before an exposure is started.

"MILLIAMPERAGE" REGULATOR "H" - The regulator "H" serves to regulate the filament current of the x-ray tube as indicated on the filament scale of the voltmeter just described. This regulator is of the magnetic type, and therefore stepless, and it is possible to make exact, precise settings of milliamperage. This regulator may be adjusted while the tube is passing current. It is usually necessary to make some slight adjustment from the preset value as made on the filament meter. The regulator is so designed that 30 M.A. will be secured at about 90% of the total rotation of the knob when operating on the radiographic setting. It will be observed that the caption "H" for this control is enclosed in a red circle to indicate that care must be exercised when operating so as not to overload the x-ray tube, particularly on the radiographic settings.

CIRCUIT "BREAKER" "J" - Knob "J" serves to close the operating contacts of the circuit breaker, which serves as a safety device in the primary circuit of the high-tension transformer is overloaded. Thus, if a shockproof cable becomes defective, or if an x-ray tube is considerably overloaded, or if some part of the high-tension circuit of the transformer should become defective, this overload will immediately be reflected to the primary, and cause the magnetic circuit breaker to trip its toggle switch. It should be explained here that the toggle mechanism of this circuit breaker is double acting, and if an overload occurs, it is not possible to hold the circuit closed against this overload. This prevents possible damage to the equipment by careless operation when an overload does occur. The contacts are closed when the button is pushed down, and open when the button is up.

This breaker has been adjusted at the factory to trip at about 25 per cent overload in current, and no subsequent adjustment should be necessary. However, if some peculiarity of the source of supply should make adjustment necessary, access to the adjusting screw can be gained through the large circular opening in the rear of the control unit which is normally 3 inch diameter covered by a large snap on "dot" plug. This adjusting screw is provided at the extreme lower part of the circuit breaker, and the tripping current is raised by lowering the screw, i.e., by turning the screw counterclockwise. Make certain that the locknut is set after the adjustment is made.

"MILLIAMMETER" "K" - Scales "K" and "K" of the milliammeter indicate the current passing through the x-ray tube, and with the radiographic-fluoroscopic safety switch (B) in the radiographic position, the upper scale of the milliammeter should be used, and correspondingly, in the fluoroscopic position, the lower scale of the milliammeter is in operation. It should be noted that both instruments are provided with switches for temporary illumination by simply depressing the small button on the bottom edge of the meter. For continuous illumination, it is only necessary to grasp the button, depress inward, and rotate. It should be especially noted that part of the scales of the milliammeter are printed in red, indicating that operation is in the danger zone, and the milliamperage should be lowered by adjusting the milliamperage control counterclockwise. Special attention has been

devoted to the design of these instruments to give maximum service under extreme conditions. They are provided with double windows spaced 3/16ths of an inch. The windows are made of transparent plastic to prevent breakage. To prevent accumulation of charges on the inner window nearest the movement, this surface is treated with a special chemical emulsion. The whole instrument is then suspended in Airfoam rubber and held securely by a metal frame.

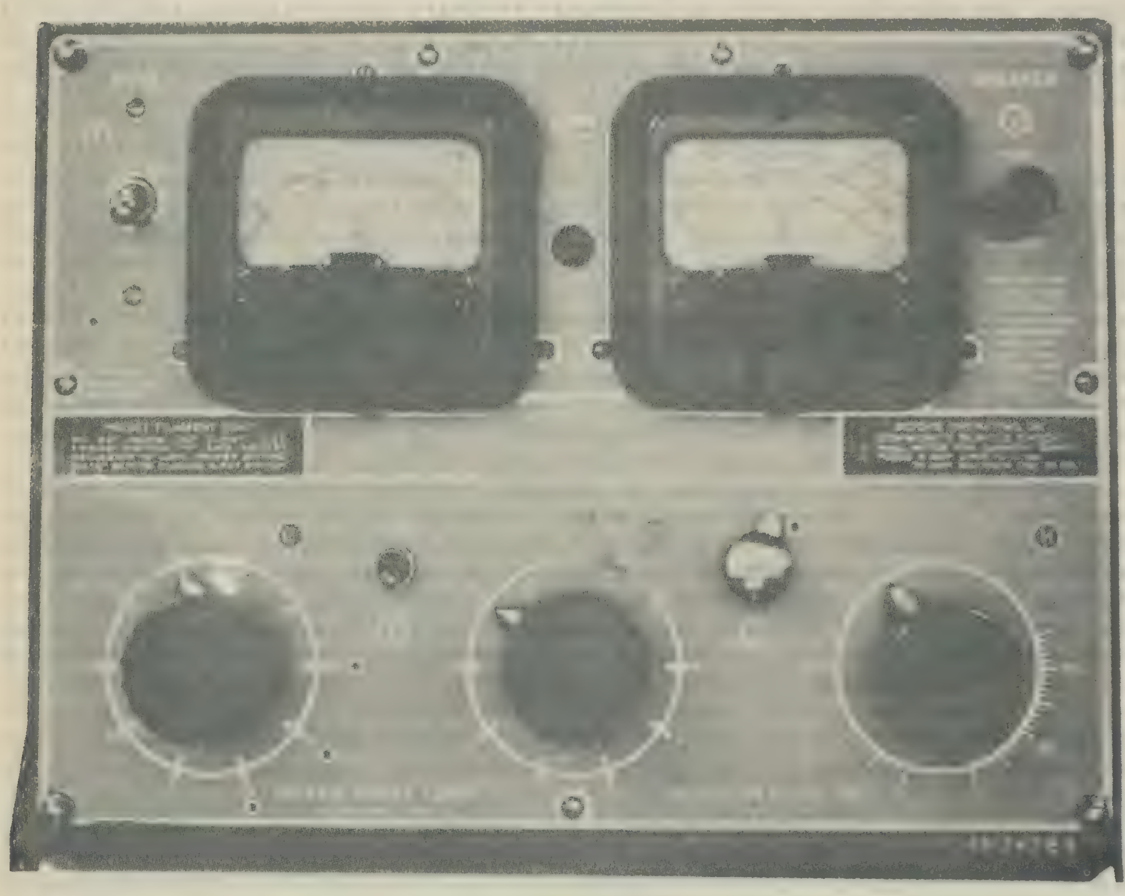


Figure K

If the lamp under the red pilot light in the center of the control panel is burned out, it can be replaced by removing the milliammeter but not disconnecting the leads. The meter is simply turned back sufficiently to reach in the aperture and release the lamp and socket. After replacing the lamp, the lamp and socket can be again placed into position and the milliammeter again secured in its original position.

It should be noted that while all the illustrations show rectangular meters, it has been necessary on some machines to substitute round meters because of the restricted production capacity of the meter industry. The round instrument has the full approval of the Surgeon General's office and it is identical in electrical characteristics to the square instrument.

TERMINAL PANEL - Figure L depicts the front of the control with the cover removed, which exposes the terminal panel. The terminal panel includes the two

main line fuses and all the connecting studs to which are connected the various leads for the receptacles at the rear of the control. Two adjusters are provided, one for the x-ray filament circuit, and one for the line. The line adjuster should be set to the tap corresponding to the line voltage. The x-ray filament adjuster is provided for some possible contingency where more or less voltage would be necessary for filament excitation. Normally this filament adjuster is set by the factory on the 104 tap and it is then only necessary to make adjustments on the line voltage, and the correct voltage will automatically be supplied to the filament circuit.

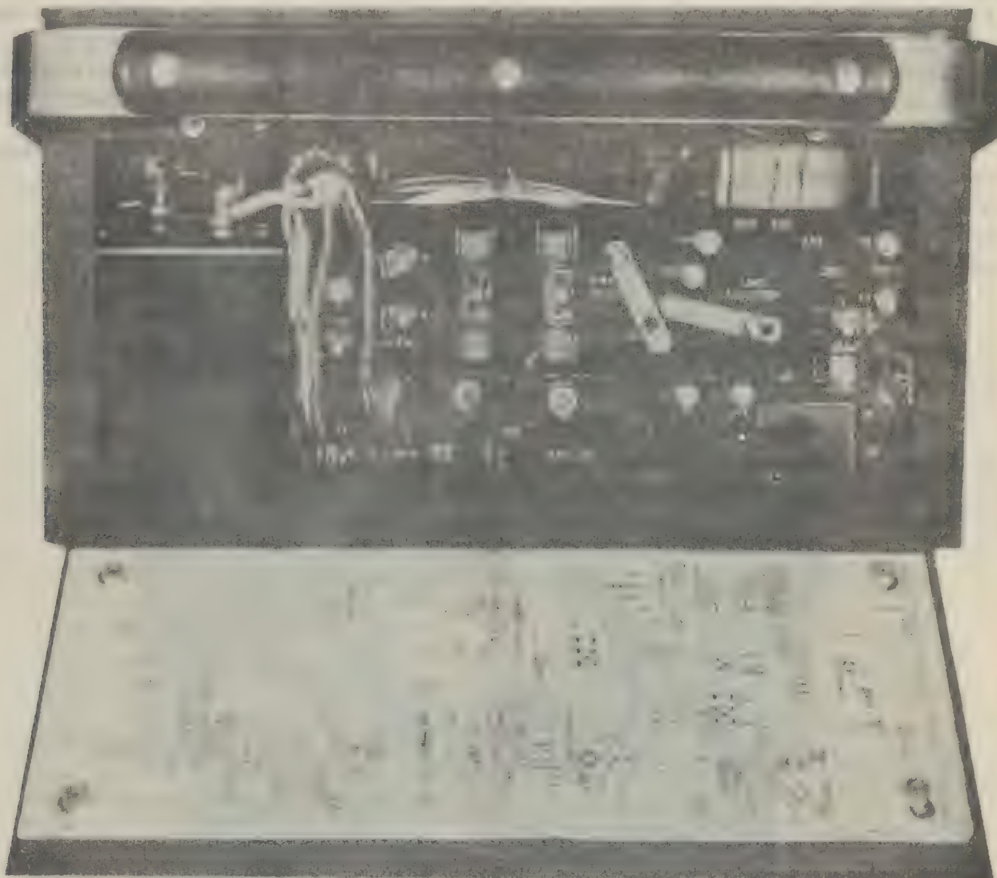


Figure L

"FLUOROSCOPIC M.A. LIMITOR" - In the lower righthand corner of the terminal panel will be noted a small knob and a nameplate indicating "Fluoroscopic M.A. Limitor". This knob is provided to adjust the limit of milliamperage on the fluoroscopic setting. This provision is necessary since lines will vary as to capacity and, while two lines may have the same voltage under no load conditions, they will vary considerably when loaded, and it may be necessary to adjust this filament limitor to a higher value if the line is exceptionally poor. Normally this adjuster should be set for the gas electric generator and it should not be disturbed unless an emergency arises on a community line.

It is well to set this limitor so that the maximum milliamperage possible with the filament control set to its maximum position will be 6 to 6½ milliamperes. This

adjustment is made by first setting the fluoroscopic limitor counterclockwise to its minimum setting, then starting an exposure by depressing the footswitch and checking the milliamperage with the filament control "H" set to its maximum position. Normally the milliammeter will indicate about 2 or 3 milliamperes under these conditions, and the limitor should now be rotated clockwise until the milliammeter reads between 6 and 6½. The limitor should be left in this position and any future adjustments of filament current should be made with the regulator "H".

LINE ADJUSTER - Before this apparatus is connected to a community line, the wall or service meter should be thoroughly inspected to be certain that the voltage and the fuses are of sufficient capacity as indicated on the operating panel of the control. If a voltmeter should be available, the line adjuster should be placed on the tap corresponding to this voltage. For instance, if the line measures between 100 and 108, the adjuster should be set on 104; between 108 and 116 set on 112; between 116 and 124 on 120; between 124 and 132 on 128.

Figure M

In case a voltmeter is not available, the line voltage can be adjusted by using the meter in the control, providing that the voltage is between 100 and 130 volts, or between 205 and 250 volts on later models. In this instance, the major kilovoltage selector should be set to "6" and the minor selector should be set to "4". It is wise to set the line adjuster strap to the 250 volt setting (when available), noting the reading of the kilovoltmeter when the main switch is turned on. If this reads less than 70 the strap can be retarded to the point when the kilovoltmeter reads approximately 70. At this point the line adjuster is set properly. If the line adjuster is set properly, the kilovolt meter will indicate "70". If the meter reads more than this, the adjuster should be set to a higher

step, which will reduce the reading on the meter and vice versa if the meter reads lower than 70, the adjuster should be positioned to a lower voltage value.

RECEPTACLES - On the rear of the control, Figure M, will be noted six receptacles and a nameplate which shows views of these, indicating the proper connection for each accessory and cable. It will be noted that no two plugs are alike, and it is only necessary to plug the proper cable in the receptacle as marked. It should be pointed out, however, that if the apparatus is not being used for localization purposes, it will not be necessary to plug in the localization lamp. Likewise, if the machine is to be used only for fluoroscopy, it is only necessary to use the footswitch. If the machine is to be used only for radiography, it is only necessary to plug in the timer and not attach the footswitch. However, it is essential that the high tension transformer cable and the x-ray tube motor cable be plugged in. Obviously, it is necessary to attach the main line.

"TOOL COMPARTMENT" (SPARE PARTS) - On the rear of the control unit will be noted a small panel secured with two thumb nuts and marked "Tool Compartment". Removal of the thumb nuts gives access to this compartment, which contains the instruction booklet and such simple tools as to make emergency repairs or adjustments. Also included are a number of spare parts for possible service in case of damage.

The tools included are as follows:
- One five-inch screw driver.
- One four-inch screw driver.
- One special Phillips head screw driver.
- One pair of combination pliers.
- One No. 8 Allen head screw wrench.
- One No. 10 Allen head screw wrench.
- One 1/4-inch Allen head screw wrench.

The spare parts include the following:
- Four spare meter bulbs.
- Four spare pilot light bulbs.
- Four localizer bulbs.
- One relay contact spring.
- Four contact levers for selector switches.
- Two contact levers for selector switches.
- Two aligning levers for selector switches.
- One footswitch mechanism.
- One main line plug.
- One voltmeter switch.
- One switch assembly for the radiographic-fluoroscopic safety switch.
- One roll of friction tape.
- One small roll of slow burning wire.
- Four 30-ampere fuses.

In addition to the above parts, there is also included an assortment of screws, nuts, set screws, and lock washers, such as are used throughout the assembly of the apparatus.

AUTO TRANSFORMER - In addition to the parts mentioned above, the control unit contains an autotransformer which, when connected to the line through the main switch, serves as a means of dividing the voltage for proper distribution to the selector switches and for supplying the proper voltage to the filament circuit and the remote control main relay. It includes a separate insulated winding for energizing the illuminating lamps, localization lamps, and the pilot light.

CONTACTOR - The cabinet contains a magnetically controlled main contactor which closes the primary circuit of the high tension transformer. The contactor is enclosed in a tight metallic case to reduce noise and to prevent any damage to contacts in assembly. It also reduces the possibility of explosion if the unit is used in proximity to any explosive vapors, however, this practice should be generally avoided, but where absolutely necessary, all switches on the control must have been preset so that the only switch in actual operation by the operator will be the footswitch. It would be unsafe, for instance, to set the selector switches in the presence of any explosive vapor.

The timer and footswitch while initiating the exposure simply energize the coil of the main contactor and its contacts close the primary circuit. In addition to these main contacts, this contactor incorporates a set of auxiliary contacts which open when the main relay closes. These contacts are connected in series with the localization lamps so that any time the x-ray tube is energized the lamps are extinguished. It should be noted here that the initial closure of the main circuit is made through a small resistance unit, which is subsequently shunted out on final closure of the relay. The difference in the time between the closing of the circuit through the resistance and the final closure is in the neighborhood of 1/100th of a second, but is sufficient to absorb initial surges. In addition to acting as a surge absorbing means, this resistor serves as a buffer as the switch opens and thereby prolongs the life of the contacts.

The contacts of this relay require accurate adjustment in order to hold the initial surge voltages to a minimum, and to this end accurate adjustments have been made at the factory on contact spacings. These spacings are as follows: The stop screw is first adjusted so that the distance between the armature and the yoke member, around which the coil is wound is 3/8 inch maximum, and at the same time the distance between the spring contacts on the armature and the resistance contact should be 1/4 inch. The distance between the spring contacts on the armature and the double main fixed contacts should be 15/32 inch. If any repairs or adjustments are made on this relay, these dimensions should be accurately checked before re-installing the relay in the case.

CONDENSER - A three section condenser is supplied and one connection of each condenser is connected to the frame of the control unit. The three condensers are connected to the three leads which connect to the x-ray tube motor cable. This condenser is used to dissipate any charge which would tend to build up on these leads if a high tension surge occurred such as the breakdown of a shockproof cable or the like.

CALIBRATION OF FILAMENT SCALE "G" (PRESET FILAMENT VALUES) - Figure L also depects the technique chart and the filament calibration chart for the apparatus. The use of the technique chart in radiography will be more fully covered in a separate section.

It is quite essential to have a calibration chart of the filament setting for various milliamperages which will be used with different techniques, so that the setting of the filament control can be anticipated rather than to make a test exposure for each case. Also, since the wave form or the characteristics of the current delivered by the gasoline generator are somewhat different from that delivered by a community power circuit, it is necessary to have a calibration of this type for both types of service. The procedure is the same in both instances. A presetting of 5, 15 and 20 M.A. will probably be required for the gas electric generator, and in addition to these a 30 M.A. setting for the community line.

This calibration is best established at about 70 P.Kv., and the kilovoltage selectors "C" and "D"should be adjusted until the kilovolt meter indicates this value. The filament control "H" should be rotated counterclockwise to the stop. Then on the 5 M.A. setting, set the radiographic-fluoroscopic safety switch to the fluoroscopy position and depress the footswitch. A very low reading will probably be observed on the milliameter, and the filament control should be rotated clockwise until the milliammeter registers 5. The exposure should then be turned off by releasing the footswitch, and then by throwing the voltmeter toggle switch "F" to the position marked "Check Filament" an indication will be observed on the voltmeter scale marked "Filament" (Scale "G"). This should be recorded so that at any future time that a 5 M.A. setting is desired on the line which is being used for the test, it is only necessary to throw this switch "F" to the position marked "Check Filament" and adjust control "H" to this calibration value. In the correct operating sequence the same procedure as outlined should be followed for the remaining points along this chart, but it will not be necessary to start each check with the filament control rotated to the zero milliamperage position but simply increased from its preceding calibrated point. Thus the calibration current at 5 M.A. would be recorded and the successive settings of 15 and 20 on the gas electric generator would be made, and on the community line 5 to 15, to 20, and on to 30 without returning the filament control to the lowest point for successive calibration points.

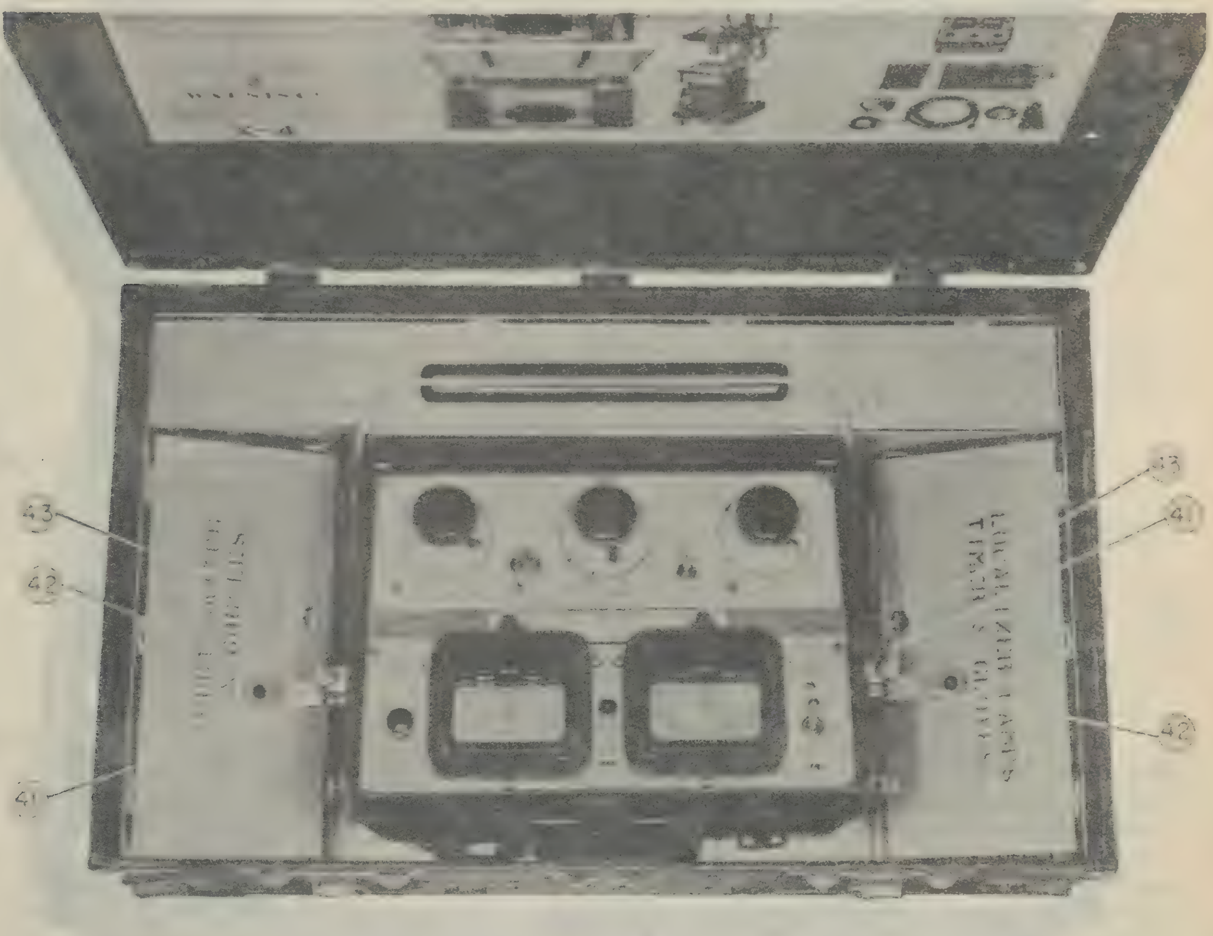


Figure N

PACKING OF THE CONTROL UNIT AND ACCESSORIES (CHEST X-4) - Figure N illustrates the packing of the control unit with the accessory cables and parts. The chest has been provided with an internal steel liner with reinforcing plates and compartments for the individual accessories. The parts packed into this chest are as follows:

1. The control unit proper.
2. a. Kit of tools.
   b. Kit of spare parts.
   c. Instruction manual.
   d. Eastman "Fundamentals of Radiography".
2. The timer (50).
3. The footswitch (49).
4. The localizer lamps with cable and plug (51).
5. The main line cable (45).
6. The lead rubber apron (46).
7. Lead rubber gloves (47). May not be included.
8. Red goggles (48).

Figure N illustrates this chest with all components in place and with the lid open. It will be seen that the control unit is fitted in the center, and is held down be means of two clamps which engage holes in the handle, which are drawn down by means of the two large wing nuts. It will also be observed that these clamps have a projecting lug fitted with rubber bumpers which bear respectively on the

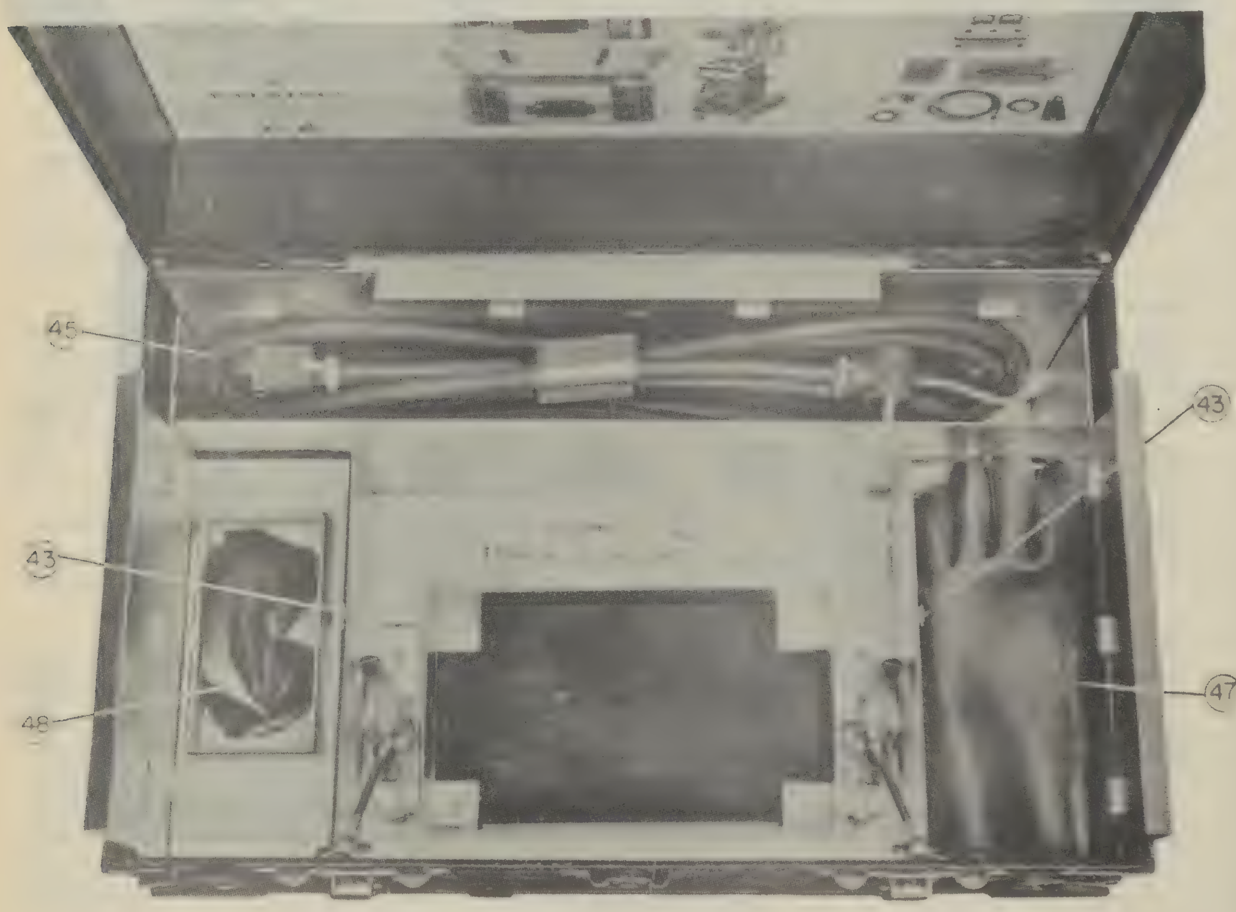


Figure P

lids of the two outer compartments. The projecting push handle of the control bears on a long plywood strip fitted to the long compartment, and thus it will be seen that when the control unit is in place and secured, all compartments are held closed and cannot be opened until the control is removed.

In order to distribute the strain of the draw bolt on the bottom of the chest, the ends are attached to an angle which has been doubly reinforced and in addition is riveted to the bottom of the case at this point. Figure P illustrates this reinforcement very clearly. It also shows the well into which the lower section of the control cabinet is fitted. The bottom of the control rests on heavy felt which is relieved at the point where the felt feet of the control are located, so that the weight and pressure of the draw bolts is distributed over a large area.

ACCESSORIES - Figure P also illustrates the position of the various accessories in the compartments. All the compartments are marked for their respective accessories so there should be no difficulty in relocating them when dismantling and preparing for transportation.

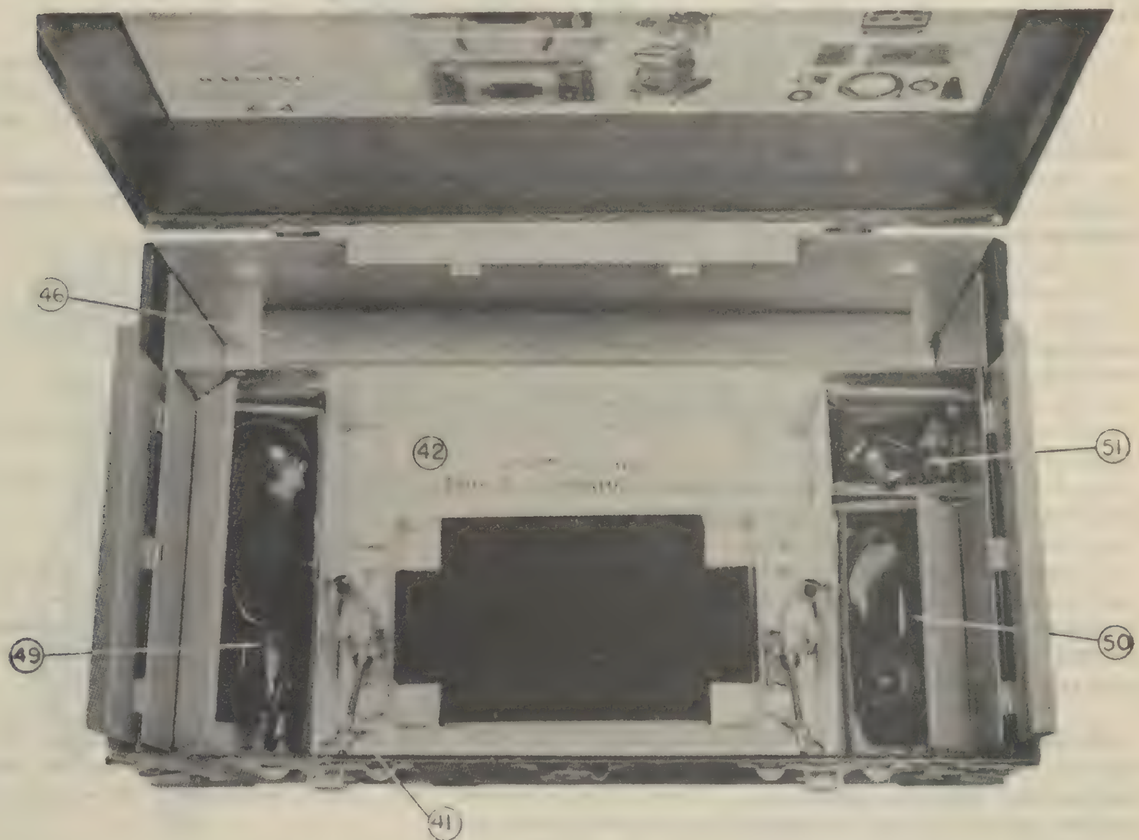


Figure Q

Figure Q shows all compartments open through to their lower sections. The footswitch "49" is shown on the left, and the timer "50" and localization lamps "51" on the right. These sections have corrugated liners which should not be removed, and after the units are in place the internal lids are closed down and the latches turned to hold them. Above the footswitch compartment a triangular compartment is arranged for the goggles "48" which are packed in a small cardboard

container Figure P. It should also be observed that as the lid of this triangular compartment closes down, a hole in the lid allows the end of the cross arm lock "43" to project through it, thus preventing it from turning. The object of this construction is to prevent any movement of the footswitch in its lower compartment if the upper triangular compartment is empty or not entirely filled. This same construction is utilized on the righthand side of the chest where the triangular compartment is occupied by a pair of lead rubber gloves, "47" Figure P.

A lead rubber apron "46" will pack in the long compartment with the main line cable "45". The lead rubber apron should be rolled after it has been folded to the proper length to allow entry into the compartment.

OPERATION OF THE UNIT - It is assumed that the tube is properly positioned with respect to the patient, and the order of operation for fluoroscopy will be in the alphabetical sequence as shown on the lettering of the nameplate. Usually, as a precautionary measure in operating the control, it is advisable not to turn on the main switch unless the circuit breaker button is in the open or up position, the filament control turned to a low or counterclockwise position, and the major kilovoltage selector not above the No. 8 position.

1. The main switch may now be thrown to the "ON" position and the red pilot light in the center of the control should be illuminated. The kilovolt meter should indicate and the meter should be illuninated, providing that the switch is in the "ON" position.
2. Since the machine is to be used for fluoroscopy, the radiographic-fluoroscopic safety switch "B" should be set to the fluoroscopic position. The kilovoltage selectors "C" and "D" should then be set to the desired Kv.
3. The kilovoltage will be indicated on the instrument under scale "E".
4. Switch "F" should now be set to the "Check Filament" position.
5. The milliamperage control should be adjusted to the proper filament setting as indicated on scale "G" of the voltmeter corresponding to the milliamperage desired.
6. Make certain that the footswitch is not depressed.
7. The "Breaker" button "J" should be pressed, which will reset the toggle mechanism.
8. Depress the footswitch, which will cause the "Milliammeter" to indicate and the lower scale "K" should be read.

The same procedure as outlined above should be followed for radiography with the exception that the radiographic-fluoroscopic switch "B" should be turned to "radiography" and the timer will be used as the exposure initiating means instead of the footswitch which now becomes inactive, and the upper scale of the Milliammeter "K" should be read.

ASSEMBLY OF THE TRANSFORMER AND TUBE WITH THE TABLE - Photos on pages 34, 35 and 36 show a layout of the transformer and control unit with relation to the table used for localization. It will be observed that the transformer is adjacent to the table leg on the operating or carriage side.

The high-tension transformer is placed in position first and the cover released and folded all the way back and down. Next, the x-ray tube is removed from its chest and attached to the carriage of the table. The shockproof cables, after thoroughly cleaning and coating with vaseline, as outlined previously, are next attached individually by plugging one end of the shockproof cable into the transformer and holding it in position by means of the threaded cap. With one end attached, the cable is uncoiled to relieve any twists or bends and attached to the

carriage of the table with the supports provided. The cable is then carried down under the table and the other end plugged into the x-ray tube and the cap threaded down tightly. The tube motor cable is then plugged into the receptacle provided and carried back to a point where it will be ready to plug into the control.

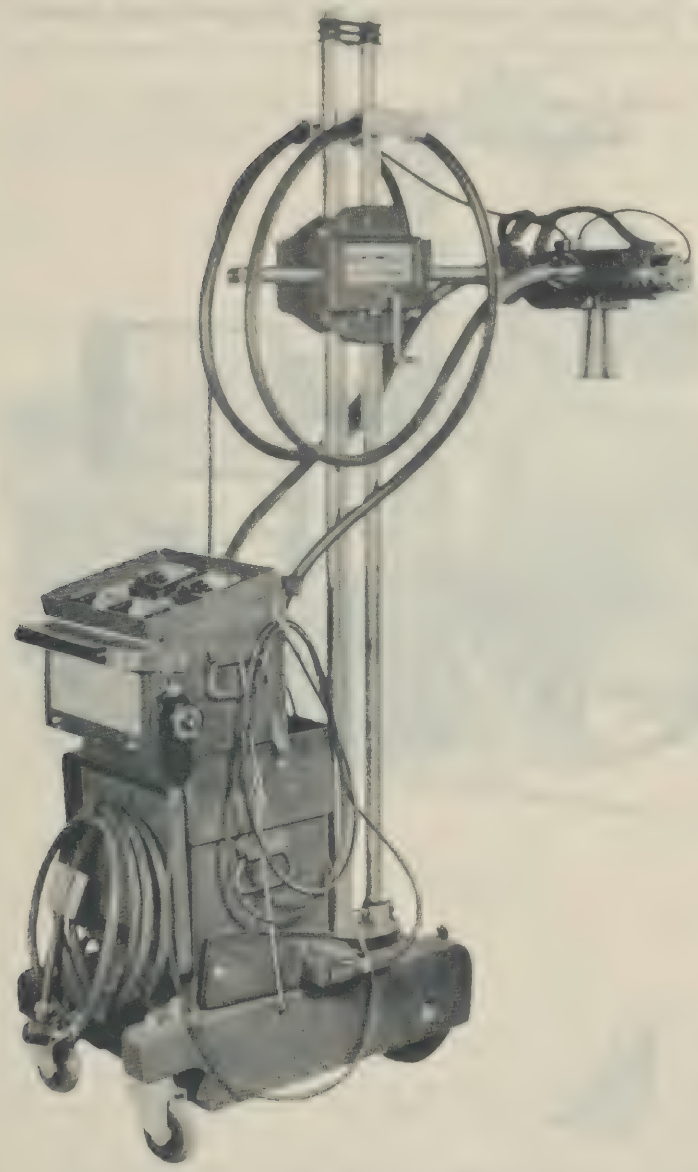


Figure BB

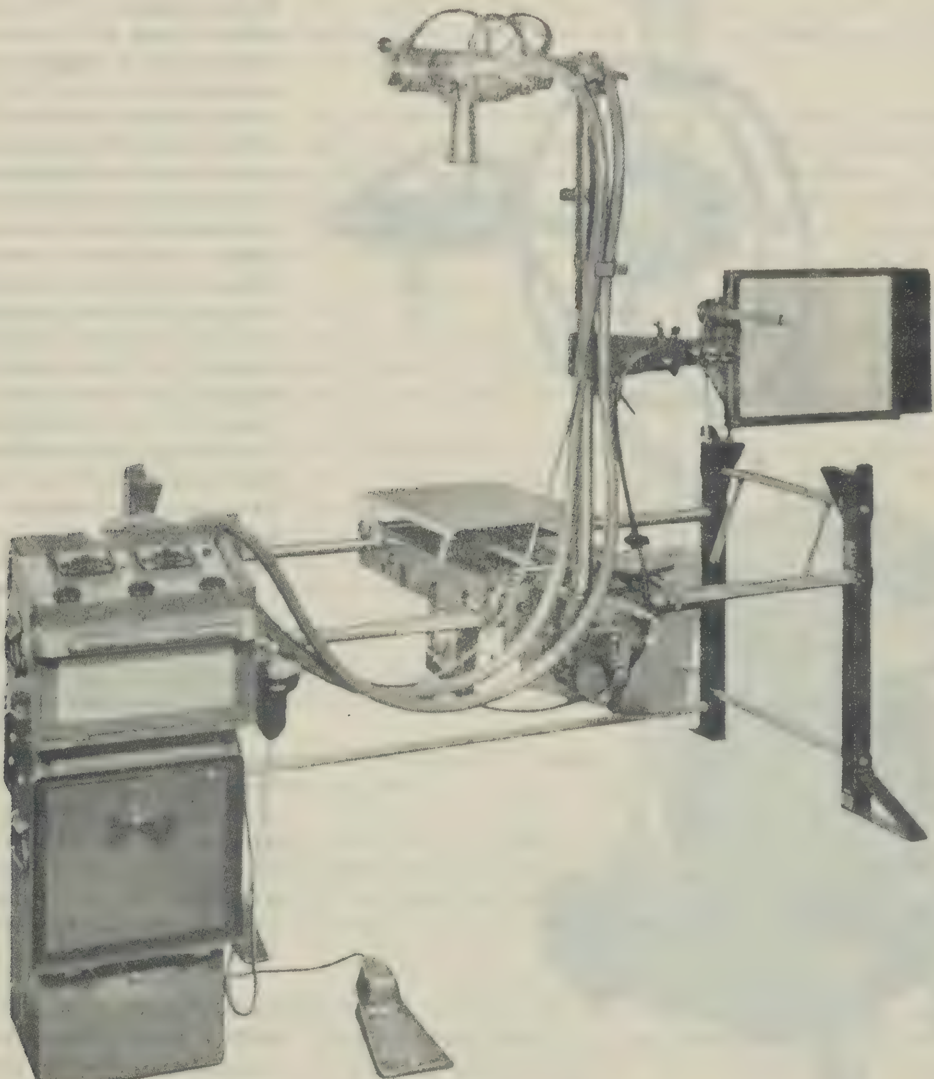
The control unit should now be removed from its chest and placed on the transformer. The primary cable from the transformer should be plugged into the receptacle provided on the rear of the control and the other end of the tube motor cable also plugged into the receptacle provided. The footswitch and localization lamp cord should be removed from the chest and placed in position and plugged into the receptacle provided. Finally, the main line should be attached to the rear of the control unit, but before connecting it to the main line or gasoline generator it would be well to first observe that the main switch is in the "off" position. When connecting the line plug to the line receptacle, attach the ground clip to a good ground, either to the frame of the wall meter box or a projecting screw or stud, When connecting to the gas electric generator attach the clip to the frame by means of a projecting stud or frame member. Operation of the control should follow as outlined previously.

MOBILE UNIT ASSEMBLY - The mobile base and tubestand should be set up as described under "Unpacking and Setting Up of Mobile Base and Tubestand". Page 4.

The cable support slides should now be pushed to the top and the shockproof cables attached, by inserting one end of the shockproof cable into the jacket provided on the top of the transformer and screwing down the threaded cap tightly. The cable should be carried up and over the support and the remainder allowed to temporarily hang free.

The tube motor cable can be removed from its compartment, uncoiled, and hung over the righthand cable support (facing tubestand end of the mobile base).

The shockproof tube can now be removed from the chest (as described under "Packing of X-Ray Tube Unit", Page 19, and attached to the horizontal arm. The individual cables, after cleaning and coating with vaseline, as outlined previously can now be inserted into the proper receptacles and threaded down tightly.



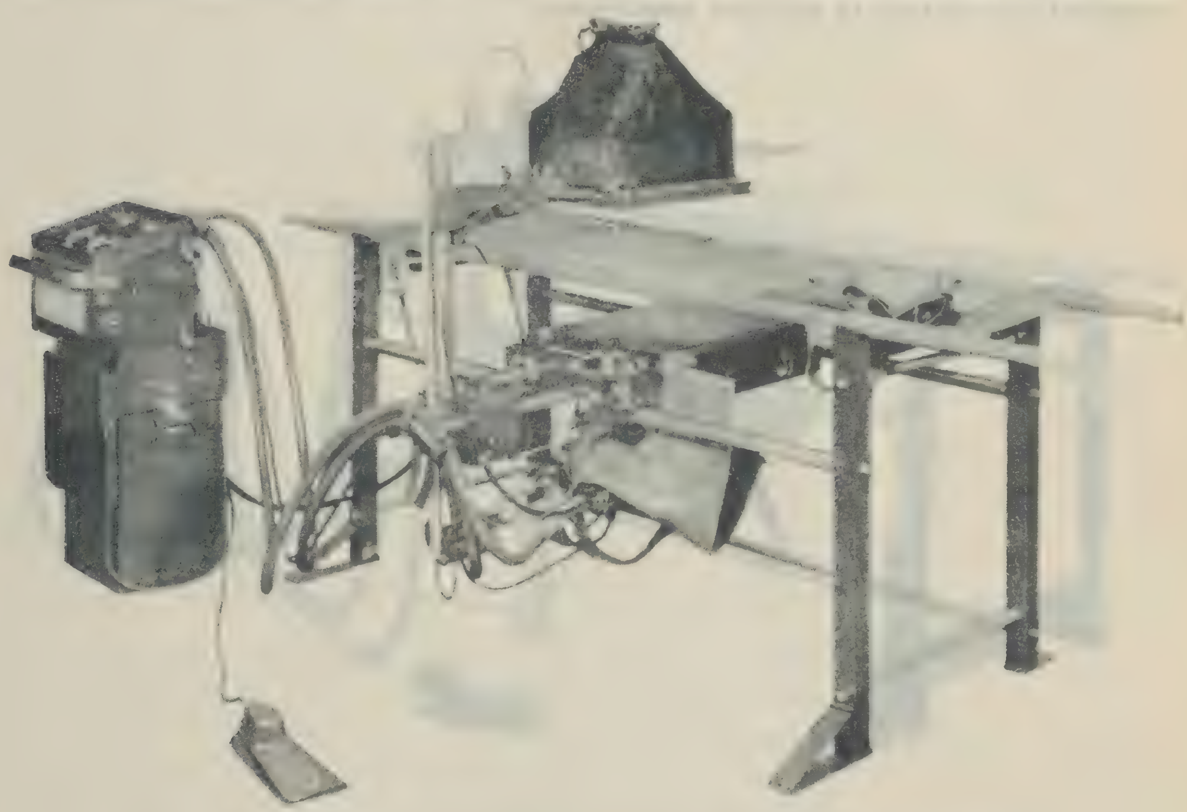
Item 96085 Generator with Localization Table from Item 96215 in Radiographic Position

The female end of the tube motor cable can now be plugged into the receptacle provided on the housing. It should be emphasized that the shockproof receptacle marked "Cathode" must be connected to the cathode end of the x-ray tube, which is likewise marked on the tube nameplate.

The H. T. shockproof cables should be loosely fastened by the web straps at the rear of the control as shown in Figure A, Page 5. The center strap is used for fixation of the tube arm while moving the unit from room to room. This strap may be tightened around rear end of arm to prevent swinging or the tube may be turned over the control and the strap used to fix the tube arm in this position as shown in illustration in chest lids.

The small cables such as footswitch cable, timer cable or localizer cables may be supported on cable hooks provided on either side of the control.

The shockproof cables may be supported either in the method shown in Figure A, Page 5, or in Figure BB, Page 33.

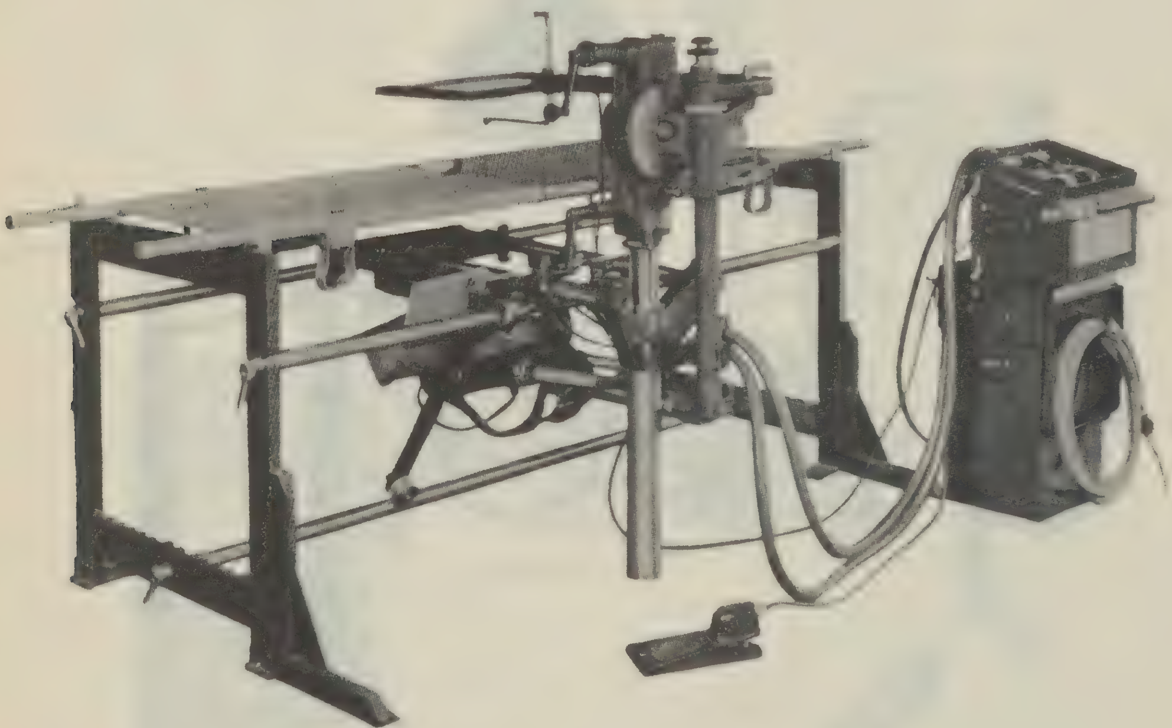


Item 96085 Generator with Localization Table from Item 96215 in Localization Position.

The control should now be removed from the chest and placed in position on the top of the transformer. After the control is in position, the two guy retaining rods, which have been left attached to either side of the channel members of the mobile base, are now removed from their packing position and the short end is passed under the control handle engaged in the hole provided in the handle escutcheon, and the long end hook engaged in the hole provided in the base, Figure A. The catch of this draw bolt is then pulled down, which tightly clamps the control and transformer

to the base. The high tension transformer plug, which has been held in position in the transformer case by means of the clip provided, is removed and the plug is inserted in the rear of the control in the receptacle as marked. The opposite end of the tube motor cable should also be plugged into the rear of the cabinet and the main line cable should be removed from the chest and connected into the receptacle provided in the back of the control. The other end of the main line cable may be attached to the source of current, either a 60 cycle receptacle, 100 to 130 volts, (later models also operate from 205 to 250 volts), or it may be attached to the gasoline electric generator (Item 96060). Attach the ground clip.

The two smaller compartments to the right and left of the control may now be opened and if the unit is provided with rubber gloves and goggles they may be removed ready for use, or if the unit is to be used for radiography these pieces can temporarily be placed in the long compartment.

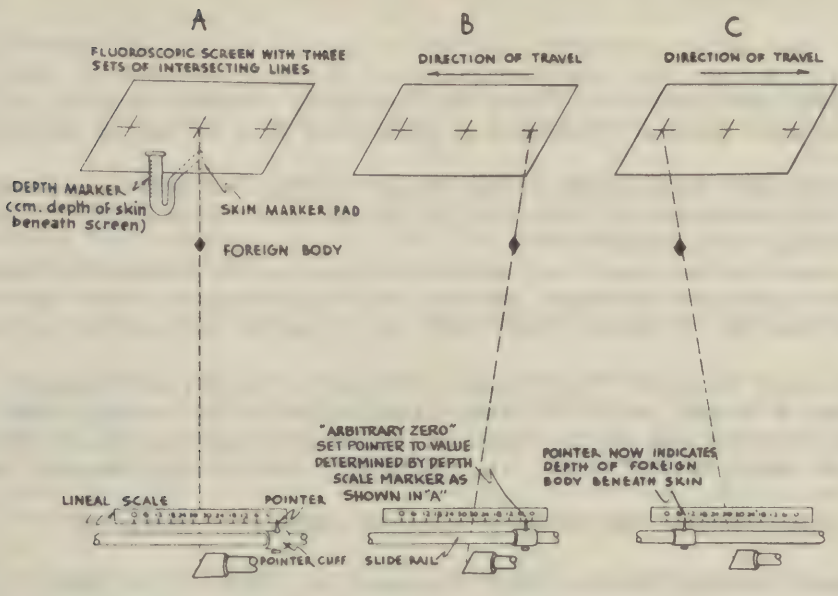


Item 96085 Generator with Items 96145 Table in Localization Position.

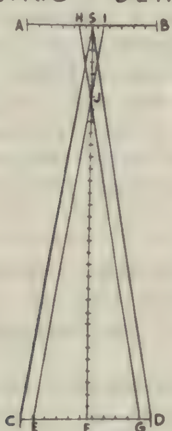
With these accessories removed, the catches holding the two doors of the lower compartments may now be released, which will give access to the hand timer, and footswitch. These may be removed and connected into the proper receptacles provided in the rear of the control. A hook is provided to receive the hand timer, and the footswitch may be placed in the position as shown in Figure A when moving the unit about as a mobile unit.

The line cable should be coiled up in a roll about 12" to 15" in diameter and placed over the hook provided in the cover of the chest when not connected to the supply line.

PROCEDURE DIAGRAM



GEOMETRIC DETAILS



FOREIGN BODY LOCALIZATION

FOREIGN BODY LOCALIZATION - Before proceeding with localization of a foreign body at an unknown depth, place depth phantom in position and check measurements. If indicated, adjust reading level on depth scale marker (this level is adjustable to provide for variations in the position of the focal spots of one or another x-ray tube).

1. Check fixation locks on "C-shaped" member; secure alignment of focal spot to center of fluoroscopic screen.

2. Align a prominence on foreign body to intersection of central intersecting lines.

3. Dampen skin marker pad with tincture of iodine or ink and adjust it to this alignment (foreign body and intersection of central intersecting lines): lower skin marker pad, until it rests on the skin, thereby marking it.

4. Read distance between fluoroscopic screen and skin by way of scale on depth marker (Figure A).

5. Shift tube and fluoroscopic screen so as to align the same prominence of the foreign body, as considered in Step No. 2, to the intersection of either of the outer intersecting lines (Figure B).

6. Slide localization scale and adjust pointer to the centimeter value coinciding with the centimeter distance between the fluoroscopic screen and the skin as measured in Step No. 4 above; clamp cuff for fixation of pointer to side rail of table.

7. Slide x-ray tube and fluoroscopic screen in direction opposite to that used in Step No. 5 above, until the same prominence on the foreign body becomes aligned to the intersection of the opposite outer intersecting lines (Figure C).

8. Read on localization scale, the depth of foreign body beneath the skin.

CONSIDERING THE DIAGRAM SHOWING GEOMETRIC DETAILS

1. A-B equals spacing between outer intersecting lines; it is equal to 22 cms.

2. F-S equals focal-screen distance (focal spot to intersection of central intersecting lines); it is equal to three times A-B, or 66 cms. (Plus or minus minor deviations in the position of the focal-spot.)

3. If a foreign body were located at S (i.e., just beneath the intersection of the central intersecting lines), for alignments of it to the intersection of the outer intersecting lines at A and then at B, the x-ray tube would have to be moved with the fluoroscopic screen for a distance equal to C-D. C-D equals A-B (i.e., 22 cms.). In the case of foreign bodies located at other levels below the plane A-B, the same ratio relationship would hold, that is the range of travel of the x-ray tube and fluoroscopic screen for the alignments of the foreign body with points A and B respectively would be 1/3 the distance F-J.

4. Since triangle E-J-G is similar to triangle J-H-I, the distance S-J bears the same ratio relationship to H-I as does J-F to E-G, that is, a three-to-one ratio.

5. H-I is equal to H-S plus S-I.

6. H-S equals G-D while S-I equals C-E; therefore, H-I equals C-E plus C-D; C-E plus G-D is the untraveled distance (22 cms. minus the distance of travel) which actually measures the location of the foreign body beneath the fluoroscopic screen.

7. The distance between the fluoroscopic screen to the skin is subtracted by making the adjustment of the pointer to an "Arbitrary Zero" as shown in diagram B and thereby the reading of the untraveled distance (as indicated on the localization scale) indicates the measurement of the foreign body beneath the skin level.

WARNINGS

Never connect the main line cable to a source of current supply without being positive that the voltage and frequency are right. If by accident the unit is connected to a 220 volt source of supply, and the line adjuster is not set properly, (see "Line Adjuster"), and if the fuses do not blow out, the equipment will be damaged.

Never permit connection of the line cable to a source of supply unless the main switch is shut off.

Never permit starting of the gasoline electric generator without having the main switch shut off.

Never connect or remove the high tension shockproof cables until the main line switch is shut off and the main line cable disconnected from the source of supply.

Under no circumstances should the main line switch be turned on with the shockproof cables disconnected from the x-ray tube, for there is always the possibility of accidental and dangerous shock from the free ends of these cables if they are disconnected from the tube.

Never use the equipment without adequate equivalent lead protection.

If the equipment has been operating for some period of time and then refuses to operate, don't jump at the conclusion that something has gone wrong. It may only be the automatic tube safety shut-off. Therefore, note the temperature of the tube housing. If it feels quite hot to the hand, it may simply be this. Of course, it is well to make sure that the main line switch, the circuit breaker, and the selector switches together with all cords, plugs, footswitches and timers are normal.

Never remove the weight of the transformer and control from the mobile unit without having first removed the x-ray tube to prevent the possibility of top heaviness and tipping.

Don't forget that moisture from the hands may contain acid, and the slightest trace of this on the terminal insulators of the shockproof cables or on the terminal bushings of the tube or transformer may cause premature failure. These parts must be wiped clean and dry, but they should not be sandpapered or otherwise scratched. A coating of clear white mineral oil, or medicinal vaseline will provide additional protection in cases of severe humidity around these terminals. A two-ounce tube of vaseline is provided packed in the tube motors cable compartment.

Don't forget when working with the gasoline electric generator, it will only run approximately two hours on one filling of fuel. Regular intervals of filling will, therefore, prevent shut-down, at periods when the equipment is needed most. Be sure to read and become thoroughly familiar with the care and operating instructions pertaining to this plant, especially that regarding its lubrication.

Don't forget that a 1/4 mm. of al. safety filter is built into the tube head directly in front of the aperture. If for any reason you remove this, it should be replaced to prevent possible burns.

Don't forget to make use of the lead aperture plates, which can easily be cut out with a pocket knife to provide any desired field area and reduce the total area of radiation to safe limits.

Don't attempt to make exposures with the hand timer by merely pressing the button. A safety device within it makes it necessary to set the time interval pointer.

Don't attempt to do any fluoroscopic or therapy work using the timer as the exposure switch. The footswitch should be used for both of these. For treatment work, a weight can be placed on the footswitch. Operating in this manner, it will

be necessary to set the radiographic-fluoroscopic switch on fluoroscopy, which automatically limits the milliamperage.

Don't forget that the milliammeter has two scales, and be certain to read the right one. The high range should be read when the radiographic-fluoroscopic switch is on radiography. The low range should be read when this switch is on fluoroscopy.

Don't forget that different lines or source of power and different x-ray tubes will upset any pre-reading filament chart that you may prepare.

Don't forget that because of difference in line voltage drop on different supplies that the kilovoltmeter can not be made to read accurately as a pre-reading device. It must be read with a load on and the load must be adjusted to the value desired, and the kilovoltage selector switches finally adjusted to the desired kilovoltage. These switches must never be adjusted while the load is on.

Don't forget to return the tools, spare parts, and this manual to the space provided for them in the base of the control so that they will be available in an emergency.

Don't forget that this is half wave self-rectified equipment, and that current is passing through the x-ray tube only on every other half wave. In other words, it is on half of the time. The milliammeter reads the average current. Therefore, when the unit is operating so that the milliammeter reads 30 M.A., this is the average current. Actually 60 M.A. is passing through the tube for half of the time giving the same effect radiographically as 30 M.A. if it were on full wave.

Don't forget to carefully retain and preserve the chests and all packing material protecting them from the elements if it is at all possible.

Be sure to attach ground clip to a good ground at the same time the main line plug is connected, and check this point before beginning operation of the generator.

POSSIBLE OPERATING DIFFICULTIES

In the case of extreme emergency it may be desirable or necessary to operate the unit even though both meters have become defective. To this end, it would be well to record in some readily accessible place the setting of the major and minor kilovoltage selector and the setting of the pointer for 5 milliampere operation. It should be emphasized, however, that this operation should only be attempted in an emergency and should be limited only to fluoroscopic work. Also, since the settings of the selectors and filament control vary from one line to another, the settings as recorded will only apply for one condition.

If the fuses in the wall meter box blow out repeatedly during operation, check the fuse capacity to be certain that they are heavy enough for the requirements. See operating instructions on control nameplate.

If fuses blow out immediately on turning on main switch:

1. Check source of current TO BE SURE that the supply is 60 CYCLES, and 100 to 130 VOLTS, (also 205 to 250 volts on later models), be certain that supply is not D.C.

2. Check adjuster straps and terminal panel to be sure that they are securely held down and have not loosened and are not touching some point of the control housing, which is grounded.

If the voltmeter does not indicate, make sure:

1. That the line cable is properly plugged into the receptacle of the supply line.
2. That there is voltage at this source of supply.
3. That there are no blown fuses.
4. That there is no break in the conductors within the line cable. That is most apt to occur at or near the point of connection of the cables to the line plug or control plug.
5. That a voltage selector switch is not set on a dead button.
6. That there are no loose connections at the distribution panel within the control.
7. That the main switch is turned on.
8. If the pilot light and meter illumination lamps are lighted, and all the above have been tried, check the wires leading to the voltmeter to be sure there are no open circuits or loose connections. If the connections are all intact, the trouble is probably a loose connection or open circuit in the meter, and it should be replaced.

If the milliammeter does not indicate:

1. Make sure that the x-ray filament is energized - this can be checked by throwing switch "F" to "check filament" position and if the meter swings off scale, it indicates that the filament circuit of the tube is open.
2. Examine the plug connections from the high tension transformer. Be sure that it is properly connected and that no wires are broken off. This can usually be determined by slightly flexing the cable near the end with the idea that if a wire is broken, its ends may be brought in contact by flexation, lighting the filament temporarily.
3. Make sure that the timer or footswitch is properly connected and that good contact is established at this point. Further, that there is no failure in the timer or footswitch.
4. That the circuit breaker knob is pushed all the way down.
5. If the footswitch is being used, be sure that the radiographic-fluoroscopic safety switch "B" is set to the fluoroscopic position.
6. If the timer is being used, be sure that the radiographic-fluoroscopic safety switch "B" is set to radiography, and timer set to some time interval.
7. Make certain that the tube motors cable is properly plugged into the tube, and also into control unit. If this cable is disconnected, the safety relay remains open and the circuit which supplies current to the main contactor is held open.
8. Make sure that the plug on the cord leading to the thermal safety switch is properly plugged in. *NOTE:* With the introduction of the steel tube housing, the connection of the thermal switch has been made internally.
9. If the main contactor closes, and the milliammeter does not indicate, there is probably a loose connection or an open circuit in the wiring leading up to the meter or possibly in the meter itself.

Milliammeter indicates, but fluctuates:

1. Slight fluctuation may be expected because of line voltage changes. This can usually be traced to line voltage by watching the voltmeter and the milliammeter at the same time. If both show a change, but if the change is greater at the milliammeter than at the voltmeter, it generally indicates fluctuation in line voltage. It may also indicate loose connection of the line cable or transformer cable.
2. If the milliammeter fluctuates severely, and the voltmeter is quite steady, it may indicate a loose connection in the filament primary circuit and

the transformer cable and plug should be checked for a defective wire; it may also indicate a loose connection in the secondary filament transformer circuit, and the connection of the shockproof cable should be checked at both ends. It may also indicate a poor connection or an open circuit in the x-ray tube, and in this instance, it is advisable to return the tube for repairs.

3. Severe fluctuation in milliamperage may indicate a gassy x-ray tube. If all the points have been checked and if visible examination of the tube through the port shows discoloration on the inside of the glass of the x-ray tube insert, or shows melting of the copper anode, it is safe to assume that the tube is gassy and was over-heated through prolonged over-exposure.

4. If the milliammeter moves a division or so and then vibrates severely, it indicates that the x-ray tube is bad.

If the circuit breaker kicks out constantly:

1. It may be caused by a defective or punctured high-tension cable. This can be checked by first, disconnecting one cable, then the other, to determine which cable is causing trouble.

2. It may be caused by a defective x-ray tube. In this event, it will usually be noticed that the pointer of the milliammeter has a tendency to fly across the scale and then back to zero as the breaker opens the circuit.

3. It may indicate a short circuit within the control or within the connecting cable between the control and transformer. This would be most apt to happen at the connections between the cable and the transformer.

4. It may indicate a breakdown of insulation, coils, etc., within the transformer. Under the very best conditions, where service is available, the cover might be removed and the transformer assembly withdrawn from the tank. However, this should never be attempted unless experienced help and the best of facilities are available.

POSSIBLE MECHANICAL TROUBLES

1. If the swivel bearings of the casters develop play after long usage, they may be adjusted by removing the caster from the Mobile Unit and clamping it upside down in a vise and removing the locknut. One or more shims may be removed to take out the play.

If the wheel bearing of the caster has excessive play, the wheel should be removed from the caster and then by releasing the locknut of the wheel bearing, it will then be possible to take-up on the conical wheel bearing. These should not be drawn up too tightly or the bearing will bind.

2. If the floor lock does not hold, (19 Figure E), loosen the locknut and turn the adjusting screw clockwise. Do not adjust so tight that the brake lever will not snap over center.

3. If the vertical carriage of the tubestand should tend to slip after considerable wear, this can be readily corrected by loosening locknut and turning the adjusting screw clockwise. (8 Figure C).

4. To secure proper alignment of the horizontal cross arm, the front and rear bearing plates have been attached to the cast aluminum housing by means of adjustable screws.

If the front of the horizontal arm is to be raised, the two lower front screws "57" are loosened by turning counterclockwise and the two upper screws "56" are tightened by turning clockwise. (Figure G).

Any misalignment of the rails of the horizontal cross arm may cause difficulty in attaching the rear stop plate "31" Figure E.

5. If the vertical carriage develops excessive play, this may be remedied by adjusting the two fibre screw "6" (Figure C).

Be sure to set the locknuts after adjusting these screws.

However, these should not be tightened to the point where they will cause a drag on the motion of the carriage.

6. If the x-ray tube tends to rotate too freely on its own axis in the hanger, the friction bearing should be adjusted by loosening capnut "21" Figure H and taking up on the adjusting nut and re-locking the capnut.

7. If the carriage should become accidentally removed from the lower mast section by improper handling, it should be replaced carefully and not put together forcibly, remembering that the gears should engage the rack and that the fibre adjusting screws will fit closely. It may be necessary to readjust the fibre screws as in "5" above.

8. If the unit is repeatedly exposed to severe weather conditions, it will be well to check the various bearings which require lubrication.

a. Main Vertical Mast Bearing "55" Figure C should have a light coating of grease occasionally.

b. The swivel bearing of the casters should be greased when this bearing does not move freely.

c. A touch of grease on the heavy spring members of the floor locks will make them operate much more freely, (this point is reached through the slot in which the lever of the lock operates). (19 Figure E).

REPAIR OF UNITS - Before attempting to make any repairs, it is recommended that you first become completely familiar with the apparatus to be repaired. The instruction manual furnished with the x-ray unit and stored in the tool compartment in the bottom of the control should be thoroughly studied. This instruction manual is reached by removing the tool compartment cover from the lower back of the control of Item No. 96085.

A complete and accurate diagnosis of the trouble is essential before attempting a repair. Do not jump at conclusions. Attack the problem from all angles. Prove to yourself by sound reasoning and by unbiased tests that a definite repair is necessary.

If, after your diagnosis of the trouble, you find that a definite repair part is needed, determine whether or not it is available in the spare parts kit in the control. The selection of parts will not suffice in all instances, such, for example, as might occur if a unit is damaged by dropping or by some severe physical impact.

METERS - If one or both of the meters are defective, either from excess friction or because they have been accidentally burned out, it will, of course, be necessary to remove them. The meters are replaced by removing the metal framework which holds the meter down to the nameplate.

After this metal framework has been removed with a screw driver and the rubber cushion pads carefully removed with it, the meter can be lifted out because the wiring connected to the meter is purposely made long enough to remove the meter without removing the entire control case. When replacing the meter, it is recommended that one lead be removed at a time and placed on the corresponding meter stud of the new meter. In this manner there will be no mistake of getting the meter leads reversed. If they are accidentally mixed up, it will be necessary to refer to the wiring diagram and to the color code on the leads to be sure of this. When replacing the meter be absolutely certain that the rubber cushion pads are carefully put back into place before putting on the retaining rim which holds the meter in place. IF REPLACEMENT METERS ARE AVAILABLE, DO NOT ATTEMPT THE REPAIR OF A METER BY OPENING THE METER CASE. THIS CAN ONLY BE DONE BY A QUALIFIED METER REPAIRMAN WITH THE PROPER INSTRUMENTS AVAILABLE. In extreme emergency the

meters may be repaired by following the meter manufacturers' recommended procedure as follows:

The following instructions have been prepared for use by untrained instrument servicemen operating under emergency conditions.

In general, an electrical indicating instrument can be cleaned and re-serviced in a majority of emergency cases for minor faults by any individual familiar with fine, neat workmanship as for example, watchmakers. The equipment necessary is listed below:

Small jeweler's screw driver such as found in sewing machine kits or surgical instrument repair kits.
Small scissors such as used in surgical work or in fine sewing.
Small pliers or heavy tweezers.
Fine tweezers as used in some first-aid kits or in a woman's make-up kit as eyebrow tweezers.
Fine steel needle with a small wood or rubber (pencil eraser) handle.
Small soldering iron as made from heavy copper wire and wooden handle.

Before attempting to perform any repairs on the instrument mechanism, a clean level place should be prepared as free from drafts, dust, and corrosive fumes as possible. The working surface should be covered with smooth, white glazed paper, or other material free from lint and fuzz. A good light source should be made available, as well as some means of magnifying the parts, if possible.

To remove the mechanism from the case, unscrew the three case to base mountings screws and then remove the back connection nuts from the studs projecting through the base.

If the pointer did not move from the zero mark on the scale, when the particular piece of equipment was placed in operation; then check all of the connections in the instrument proper. Before proceeding with this inspection, however, a check should have been made of the equipment itself to make certain that the defect was not elsewhere than in the instrument. If there is a broken connection or unsoldered joint, this should be repaired by resoldering, using as little flux as possible.

If the pointer shows signs of sticking at some particular section of the scale, it is possible that a small piece of foreign matter is wedged between the moving coil and the magnet. This can be dislodged with the fine steel needle, holding the mechanism in such a way as to sight through the opening between the moving coil and the iron magnet.

If the pointer shows signs of sticking or lagging over the whole scale arc, then the pivots or jewels may be worn or coated with dirt. Defective operation from this cause may be checked by noting the change in position of the pointer when the instrument is lightly tapped. If this motion is more than one division on the scale, then there is a good possibility that the pivots or jewels are in need of cleaning or repolishing.

To clean or repolish the pivot or jewel, unsolder the outside turn of the spring from the spring support by bringing the hot soldering iron against the support where the spring is soldered. Remove the jewel bearing locknut and carefully unscrew the jewel screw. Note the arrangement of the spring support and pointer stop on the pointer side of the moving coil. Also the insulating washers and spring support on the opposite jewel bearing assembly. This is necessary in order that they may be replaced properly.

The pivot and jewel screw may then be cleaned with a small, soft wood stick soaked in clean alcohol. The jewel surface can be cleaned with a pointed stick. The steel pivot can be cleaned and slightly polished by means of a small stick applied to the pivot surface through the jewel screw opening. When cleaning the pivots, a small brass or fibre spacer should be placed between the moving coil and the iron core so that excessive pressure is not exerted on the opposite pivot and bearing.

When replacing the jewel screws and associated assemblies, make certain that the spring is neatly soldered, and that the turns of the spring do not touch each other. Adjust the clearance between the jewel screw and the pivot so that there is just a noticeable movement in the jewel when the coil is lightly moved from side to side by a slight pressure on the pointer tip. The actual distance between the pivot and the jewel surface with the movement in the horizontal position should be approximately 0.005 to 0.002 of an inch.

No attempt should be made to remove the mechanism from between the openings of the magnet as this will in general require recharging of the magnets and realignment of the whole frame assembly. Electrical continuity of the moving coil and the series resistors may be checked by connecting a small 1½ volt dry cell in series with a head set or telephone receiver and the part to be tested. A sharp click will indicate a continuous electrical circuit.

If the pointer has been thrown off balance by severe jar or overload, it may be rebalanced by sliding the small spring adjusting weights on the brass cross arms. Use a small tweezers to hold the small spring weights and slide them along the balance arms. The two arms at right angles to the pointer are for side balance. The one arm in line with the pointer is for tail balance.

Before placing the mechanism back on the base and in the case, make certain that all the parts are clean and free from dirt and dust particles which may lodge in the movement. When mounting the case, make certain that the small zero adjusting screw in the lower portion of the case front is in such a position as to engage the forked shaped section attached to the upper spring support.

Milliammeters and ammeters can be compared with "Good" meters by connecting the two in series. Voltmeters and kilovoltmeters can be compared with "Good" meters by connecting the two in parallel.

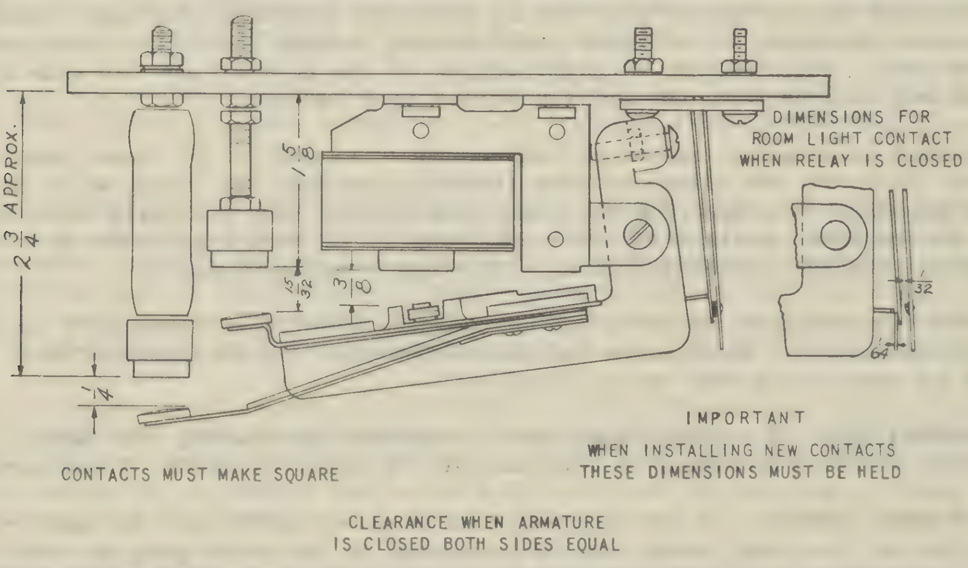
METER LAMPS - The meter lamps can be replaced by removing the bakelite meter lamp hood which is attached to the case of the meter by means of two screws.

PRIMARY CABLES - If the primary cables prove defective, it may be only a loose lead at the place where they are soldered to the cable plug or cable receptacle. This can be remedied by resoldering, or in cases where the leads are actually broken it may be necessary to cut off a few inches of the cable and completely reterminate the cable by skinning back the wires and resoldering them in accordance with the color code on the wiring diagram. Use the old cable for a sample and do the soldering and terminations in a like manner. The cable plugs will be found in Box No. 1.

CONTROL RECEPTACLES - If the receptacles on the control must be replaced, it will be necessary to remove the entire cover or cabinet of the control itself. In order to do this, first remove the meters and carefully lay them to one side. Then remove all of the knobs including the circuit breaker knob from the unit. It will be found that there are double set screws holding these knobs on to their various shafts. One of these set screws is used to lock the other one tight. Both

set screws must be loosened. It is, therefore, necessary to entirely remove the outer set screw. After the outer set screw has been removed, the inner set screw can be loosened up so as to allow the knob to be removed from its shaft. After all of the knobs have been removed and the meters also removed, the two screws holding the main switch to the nameplate should be removed. The screws holding the control case to the inner structure of the control can next be removed. It is not necessary to remove the top nameplate. On each slide of the control will be found several screws which must be removed before the control case can be lifted off the assembly. The pushing handle which is attached to the front of the case is held on by two large 1/4-20 buttonhead screws on each side. Remove both of these. At an even height from the bottom but towards the back of the control will be found a single buttonhead screw through the side of the control. This also should be removed. At the two lower corners will be found other screws which should also be removed. Two of these in the rear corner are used to hold a cable hook. After these six screws are removed on each side, the entire cover case with the nameplate attached can be lifted off the control assembly. This will give access to the entire inside of the control and the control receptacles for the various cables can be readily inspected and replaced if necessary, or the leads can be resoldered on to the present receptacles if for any reason they are broken or damaged.

INSTRUCTION DIAGRAM FOR CORRECT CONTACT SPACING IN MAIN RELAY



CONTACTOR REPLACEMENTS - The contactor is accessible only after the control case has been removed. It is in the large black metal box on the right hand side of the control looking at it from the back. In order to remove this, it is first necessary to remove the wires from the top bakelite panel. In removing them, do not bend or change the position of the wires so that they can be easily replaced on the correct terminal studs without too much wasted time in checking through the wiring. If they are removed carefully they will retain their own position so that the relay can be very easily replaced and the wires will fall right down into their own terminal positions. The relay case is fastened to the bottom of the control chassis by a screw at each end which, of course, must be removed.

Remove the entire relay assembly from the metal case in which it is contained by removing the several screws along its upper edge. The relay can then be carefully

removed and inspected. The spacing of the contacts are very important and must be held as accurately as possible. If the spacing is incorrect, it will not only affect the actual timing of the x-rays, but it will seriously affect the peak surge voltage of the equipment when the exposure is turned on. In order to reduce this surge voltage to an absolute minimum and thereby reduce the electrical strain on the high-tension system, including the transformer, shockproof cables and the x-ray tube, it is, of course, necessary to keep this to an absolute minimum and, therefore, to have the spacing of the contacts accurate. This spacing is shown on the drawing on the preceding page.

If the contacts themselves are worn very badly, as is probable after a hundred thousand or more exposures, it would be wise to replace them and to reset their correct spacing distances as shown in this print. If they are not badly worn and the relay is open, it would still be well to carefully clean them and thereby present the best possible contact area.

CIRCUIT BREAKER - The circuit breaker will be found at the extreme left hand side of the control looking at it from the back. It is accessible after the control case has been removed. The contacts and contact arms can be readily removed by unscrewing them from the bakelite panel on which they are mounted. It is important when replacing these parts that the proper spacing and proper tension be maintained on the contacts so that the contacts will be positively made when the circuit breaker toggle mechanism is in the set position and that they are without too much tension. If the tension is too great, it will require too much effort for the circuit breaker to be set and to be tripped and will make it difficult to reset it. There are spare hairpins and cotter pins in the spare parts kit in the control tool compartment if any of these become lost. Also you will find in this repair kit a complete replacement toggle mechanism in case the one becomes damaged on the unit. The circuit breaker knob is screwed on to the shaft in a clockwise direction. In order to have this tight, it is necessary to hold the shaft with a thin pair of pliers while tightening the knob.

REPLACING TOGGLE SWITCHES - The filament checkswitch or the radiographic-fluoroscopic toggle switches can be replaced only after the removal of the control case. After this is done, they will be readily accessible and can be readily replaced by unsoldering the wires and resoldering them on to the new switch obtained from this repair kit. In order to avoid any possibility of mixing up the wires, transfer one wire at a time from the old switch to the new switch, carefully soldering each one in this process. In this way they will not become mixed up and it will avoid unnecessary delay for checking and the finding of any errors.

HIGH-TENSION TRANSFORMER - If the high-tension shockproof cable jackets or cable receptacles in the high-tension transformer are broken or have sparked over and burned a pathway down the inside of the insulator, it will, of course, be necessary to repair or replace them. In order to replace these insulators, it will first be necessary to remove the protective bakelite tubes which are cemented over the extended molded end of the insulator. These can be carefully slit with a sharp knife and removed without breaking. The special jacket wrench can then be used over the extended part of the insulator to remove the flat locknut which holds the insulator into the threaded part of the transformer top. It will, of course, be necessary to lift the transformer out of the tank of oil before removing the old insulator in order to unsolder the leads on the bottom of the insulator which connects to the high-tension transformer. The connections of these leads are very important. On the cathode insulator the lead colored red, from the filament transformer, connects to the inner and outer contacts as well as to the high-tension secondary. The other lead from the filament transformer connects to the center

contact. On the anode insulator all the contacts are connected together. When the new insulators are installed, the new gaskets should be used and the locknut tightened down thoroughly with the wrench. Then recement another pair of protective sleeves over these cable jackets as this reinforces the comparatively brittle molded material which extends as part of this high-tension transformer insulator.

If the insulators are not deeply burned, and the burned area is a comparatively shallow burned line, it can be reapired satisfactorily by very carefully scraping away all of the darkened surface. A tool for this purpose can be made from a piece of steel rod or heavy wire with a short section on one end bent at right angles to its length. This short end can then be filed or ground to a scraper edge so as to make a scraping tool which can be used to remove the burned areas from the entire length of the insulator.

After it has been carefully cleaned, wiped out and dried, be sure to use plenty of clean dry white vaseline or castor oil to seal up this area when the cables are again reinserted.

Usually if the transformer insulator is burned, the corresponding terminal of the high tension shockproof cable will also be burned out and will have to be similarly treated. Never use emery cloth or carborundum paper for dressing down these areas as the abrasive particles are conductors of electricity instead of insulators as is the case of sandpaper.

If there is any electrical breakdown in the high-tension transformer itself, it is recommended that a replacement transformer is obtained from the nearest Supply Depot if possible, as it requires a highly skilled man to replace these parts in the transformer and requires special processing to do this type of work. In cases of extreme emergency, certain types of repair can be accomplished if the following instructions are carefully followed:

EMERGENCY REPAIR OF HIGH-TENSION TRANSFORMERS - Whenever possible a replacement high-tension transformer should be ordered from the nearest Medical Supply Depot when needed. If occasion arises in which no replacements are available, then it will be necessary to effect repairs of the transformer in case of breakdown.

Usually the causes of transformer failures are insulation failures. The oil may have become oxidized or the oil level may be low. Moisture may have been allowed to enter. If the oil level is low or if the oil is very cloudy in color, the oil should be replaced. If special dehydrated transformer insulating oil is not available, clear water-white medicinal oil may be used in its place. This is usually available in the Medical Departments. When refilling the transformer be sure to fill to within 3/4 inch of the underside of the top.

If the transformer fails because of insulation failure, it usually bubbles and smokes when energized. Such failures must be definitely located before any attempt is made to repair the unit. A filament transformer failure may occur by either a direct puncture of the insulation between primary and secondary or else a burning or arcing over the outer surfaces. This is usually termed surface leakage. In either event the filament transformer should be removed from the transformer tank. The secondary coil can be pushed off the primary insulation after the end iron section or end leg has been removed.

If the trouble is surface leakage and only the outer layer has been damaged, it can be removed and the transformer reassembled by omitting the outer layer. It would be recommended that the transformer should not be operated at its maximum

voltage after such a temporary repair has been made. It would be safer to reduce the top kilovoltage to 85 or 90 P.Kv.

If the insulation has been punctured, it may be necessary to replace the insulation. If no varnished cloth or varnished paper is available, a glass or porcelain tube may be used with dried hardwood wedges or spacers used to space this tube from the primary. In such cases your own ingenuity will have to be used to adapt the materials at hand. Mica, bakelite, some plastics, hard rubber, certain types of hard paper may all be used for emergency repairs if they are thoroughly dried and cleaned.

If the high-tension transformer fails, it may be a failure of insulation between primary and secondary, a failure of one or more barriers between secondary coils or a surface leakage failure. If the high-tension coils break down the failure may be in only a few turns or a few layers on the outside edge of the coil, in which case it can be repaired by removing the damaged section. Only rosin core solder should be used to re-solder the connections. Never use acid core solder. Never use friction tape or any rubber compounds that are affected by oil.

When reassembling the transformer be sure there is no moisture present. If there is any doubt, bake out the unit by putting it in an oven at approximately 150° Fahrenheit. If no oven is available a number of heat lamps from the Medical Department, or even common light lamps may be used for thoroughly drying the assembly. When reassembling the transformer be sure that every part is kept *clean* and *dry*. After it has been completely reassembled there will be air bubbles trapped in between the layers of the coils, etc. When processed at the factory, these units are subjected to a vacuum process so that all air is removed. In the field it probably will be impractical to get a vacuum for this purpose and so it will be necessary to take some special precautions before operating this transformer. To remove the major part of the air that is trapped, rock the transformer from side to side or even lay it on its side for a few minutes. Be sure the vent is closed, to avoid spilling oil. Then start operating the transformer at 25 or 30 P.Kv. and allow it to run no load at this kilovoltage for ten minutes. Then increase the voltage in 10 P.Kv. steps, running it for at least ten minutes on each step until the desired operating voltage is reached.

This will then eliminate most of the air and the unit can be operated in a normal manner from then on. If any insulation has been changed or there is any reduction of insulation or reduction of turns, etc., then the maximum allowable voltage should be reduced accordingly even if it is necessary to adapt the technic to use the lower voltage. Otherwise a more serious and irreparable damage may be the result.

SELECTOR SWITCHES - If there is an open circuit between the autotransformer and the high-tension primary terminals, it may be caused by a broken spring lever on the selector switch, either on the major or minor selector switch. Either the switch contact lever, which is the flat spring lever which rides on the small copper contacts of the selector switch, or the return contact spring lever which rides over the corrugated brass return plate may be broken. The return lever mast logically breaks before the other because of the constant flexing as it rides up and down over the corrugated plate. These corrugations serve to locate the other switch levers over the center of the contacts so that proper contact is insured at all times without burning.

To get at these switches, remove the control housing as outlined under the

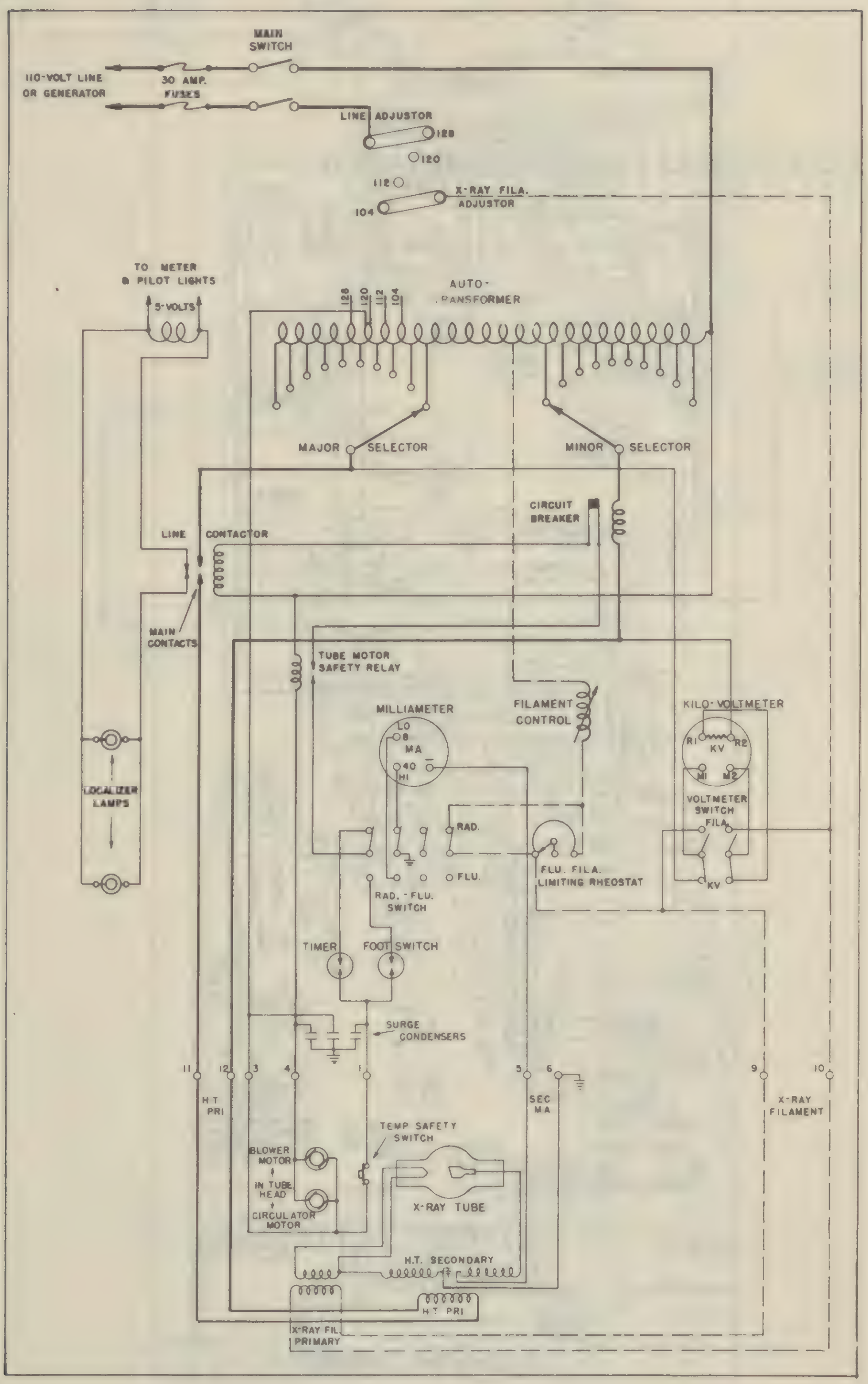
paragraph on Control Receptacles. Next remove the screws holding the switches to the metal subpanel which is exposed to view when the control cover is removed. The major selector can then be dropped a little, allowing accessibility of the switch levers. If the minor selector switch is to be repaired, it will be necessary to take out the screws holding the filament control and the circuit breaker to this subpanel. Then remove the four screws holding this subpanel down. Then if the white, slow burning lead connected to the common terminal of the major selector switch is unsoldered, this panel can be raised sufficiently to get at both the minor and major selector switches.

When replacing the switch levers, be sure that the spacing washers which provide the correct spacing of the levers on the shaft assembly are put back in the same places as they were. Otherwise there will not be sufficient spring tension on the switch levers.

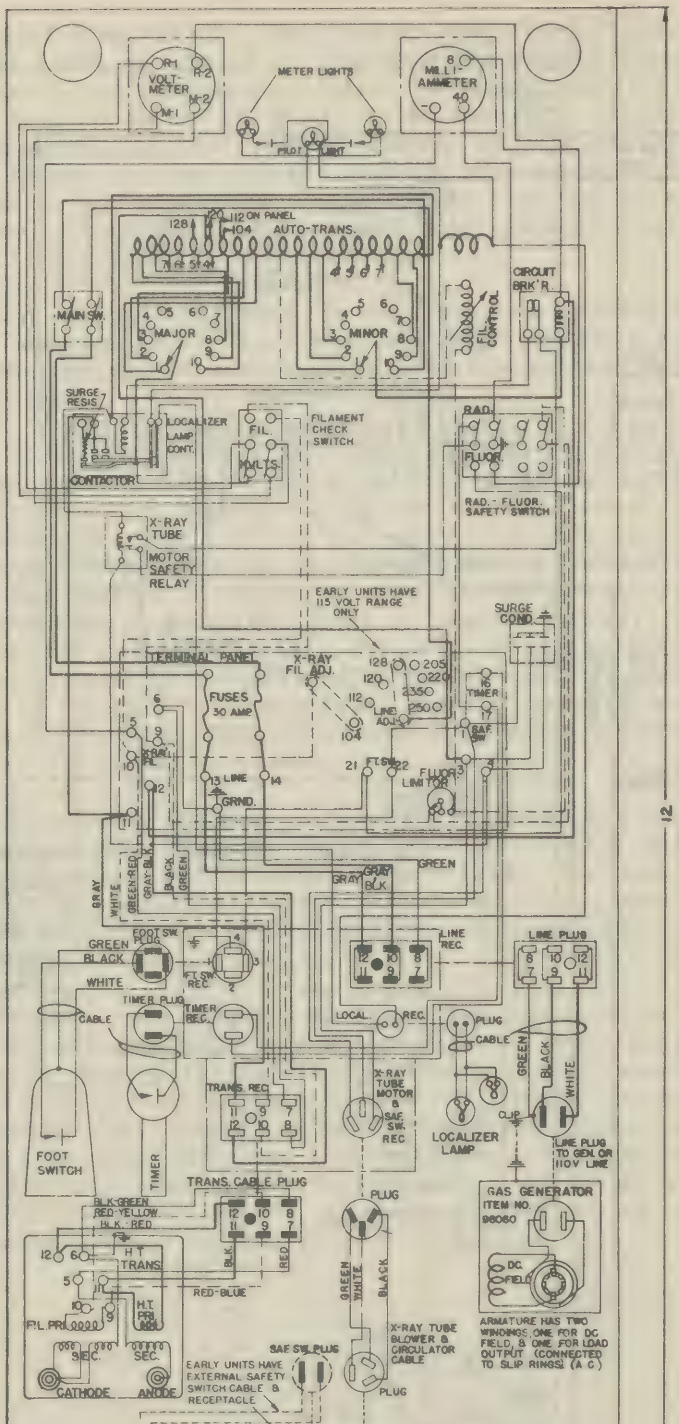
X-RAY TUBE - The receptacles in the x-ray tube housing may be replaced by removing the upper housing part of the x-ray tube which contains the blower. This is attached to the rest of the housing by the screws through the casting or the sheet metal housing into the shell of the x-ray tube housing. After this is removed, it will expose the inside of the blower housing through which these receptacles pass and are fastened. If one or more of the receptacles are removed, it would be recommended as in the other cases to replace one wire at a time from the old receptacle to the new receptacle. This wiring of these receptacles is very important because it must be properly polarized in order to make the unit operate correctly. All of the wiring connections are, of course, shown on the wiring diagram which is included in the control as well as in the instruction booklet sent with each unit.

If, for any reason, there is a damaged or defective x-ray tube, if must be returned to the nearest Medical Supply Depot for repair as it is impractical to attempt to open these tube housings in the field. The tube housing is filled with a special oil and must be specially processed and vacuum filled. Special tools are required to remove and replace the sealing ring on-each end of the tube.

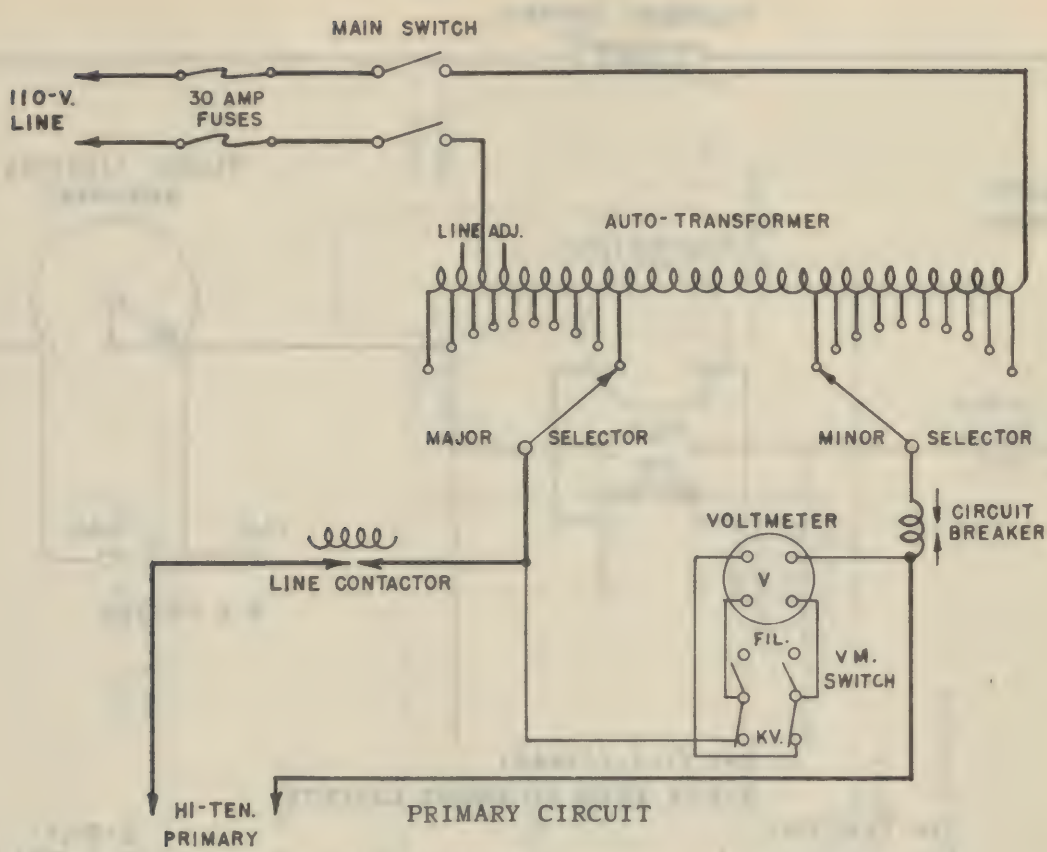
CAUTION - Whenever any repair work is done on the machine, make sure that it is done in the very best possible workmanlike manner. Great care must be exercised in any work done on these x-ray machines. Never use acid core solder or any acid around the unit for it will definitely corrode the soldered joints and cause trouble later on. The solder furnished with the unit is a rosin core type solder and only rosin flux should be used under any circumstances. Be sure that all screws and nuts are thoroughly tightened on any replacements. After any work has been done, no matter how trifling it may appear, be sure that the entire unit is tested completely and operated before turning it over for actual use.



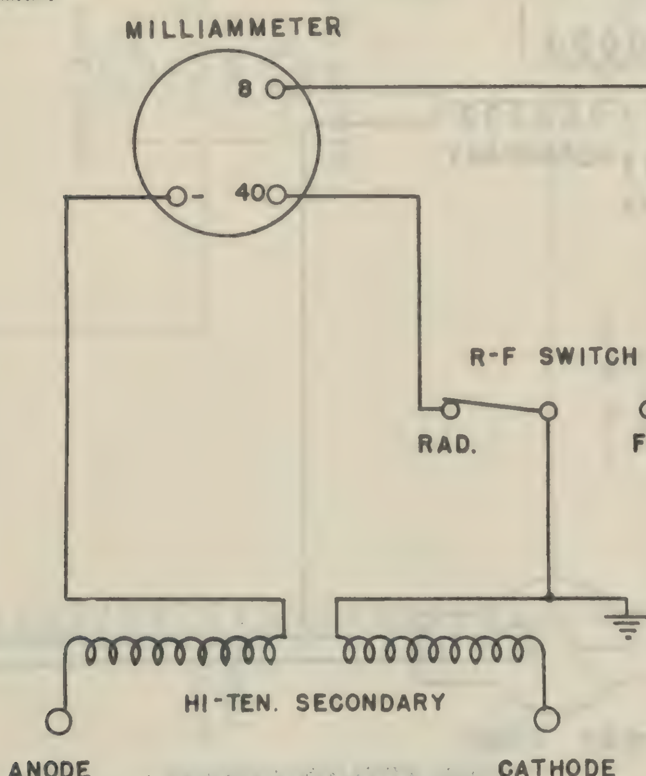
MAIN SWITCH
110-VOLT LINE OR GENERATOR
30 AMP. FUSES
LINE ADJUSTOR
128
120
112
104
X-RAY FILA. ADJUSTOR
TO METER & PILOT LIGHTS
5-VOLTS
AUTO-TRANSFORMER
MAJOR SELECTOR
MINOR SELECTOR
CIRCUIT BREAKER
LINE CONTACTOR
MAIN CONTACTS
TUBE MOTOR SAFETY RELAY
MILLIAMETER
LO
MA
40
HI
FILAMENT CONTROL
KILO-VOLTMETER
R1
KV
R2
M1
M2
VOLTMETER SWITCH
FILA.
KV
LOCALIZER LAMPS
RAD.
FLU.
RAD.-FLU. SWITCH
FLU. FILA. LIMITING RHEOSTAT
TIMER
FOOT SWITCH
SURGE CONDENSERS
11
12
3
4
1
5
6
9
10
H.T. PRI
SEC MA
X-RAY FILAMENT
TEMP SAFETY SWITCH
BLOWER MOTOR
IN TUBE HEAD
CIRCULATOR MOTOR
X-RAY TUBE
H.T. SECONDARY
H.T. PRI
X-RAY FIL PRIMARY


VOLT-METER
METER LIGHTS
MILLI-AMMETER
PILOT LIGHT
ON PANEL
AUTO-TRANS.
MAIN SW.
MAJOR
MINOR
FIL. CONTROL
CIRCUIT BRK'R.
SURGE RESIS.
LOCALIZER LAMP CONT.
FIL.
FILAMENT CHECK SWITCH
CONTACTOR
RAD.
FLUOR.
RAD.-FLUOR. SAFETY SWITCH
X-RAY TUBE MOTOR SAFETY RELAY
EARLY UNITS HAVE 115 VOLT RANGE ONLY
SURGE COND.
TERMINAL PANEL
X-RAY FIL. ADJ.
FUSES 30 AMP
TIMER
LINE ADJ.
SAF. SW.
LINE
GRND.
FT. SW.
FLUOR. LIMITOR
GRAY
WHITE
GREEN-RED
GRAY-BLK.
BLACK
GREEN
LINE REC.
LINE PLUG
FOOT SW. PLUG
FT. SW. REC.
TIMER PLUG
TIMER REC.
CABLE
LOCAL. REC.
PLUG
X-RAY TUBE MOTOR & SAF. SW. REC
LOCALIZER LAMP
CLIP
LINE PLUG TO GEN. OR 110V LINE
FOOT SWITCH
TRANS. REC
TRANS. CABLE PLUG
GAS GENERATOR ITEM NO. 96060
D.C. FIELD
ARMATURE HAS TWO WINDINGS, ONE FOR DC FIELD, & ONE FOR LOAD OUTPUT (CONNECTED TO SLIP RINGS) (A.C.)
BLK-GREEN
RED-YELLOW
BLK.-RED
H.T. TRANS
H.T. PRI
FIL. PRI
SEC.
CATHODE
ANODE
RED-BLUE
BLK.
RED
X-RAY TUBE BLOWER & CIRCULATOR CABLE
SAF. SW. PLUG
EARLY UNITS HAVE EXTERNAL SAFETY SWITCH CABLE & RECEPTACLE
10-15-41
D-27815
4 HOLES 3/8" DIA.
BLOWER MOTOR
SAFETY SW.
X-RAY TUBE
CIRCULATOR MOTOR
12

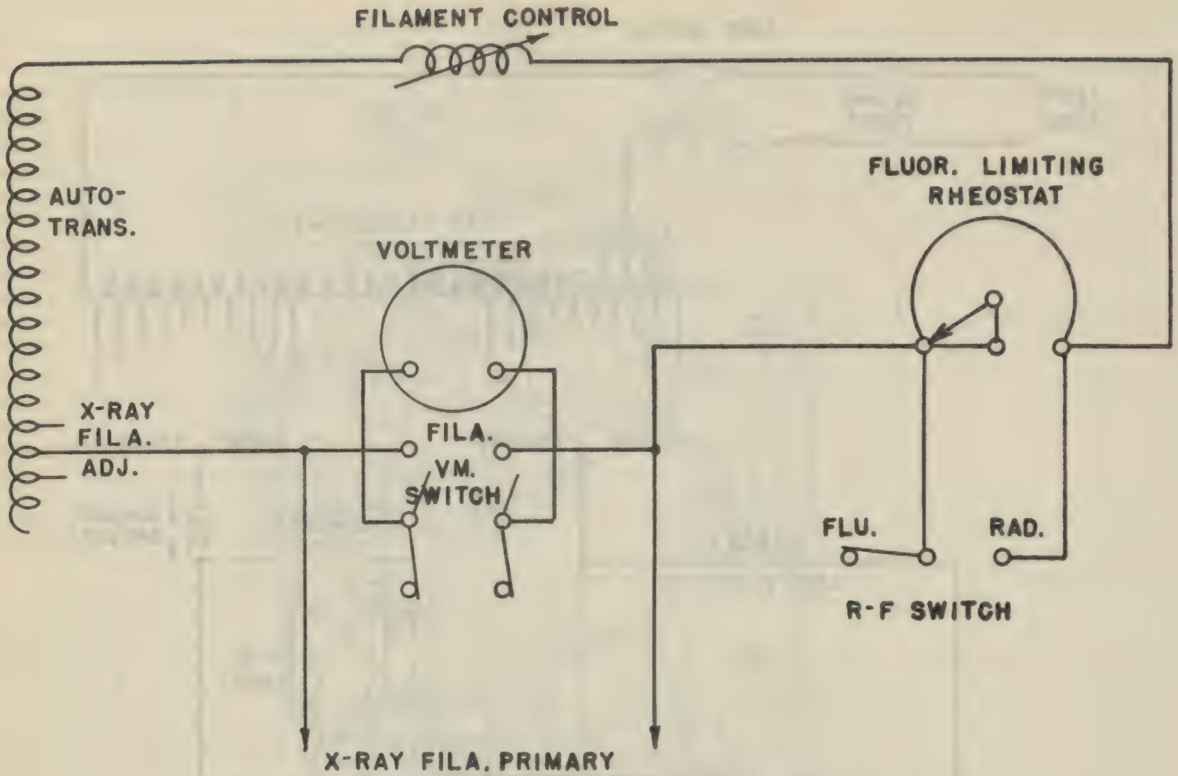
ARMY FIELD UNIT



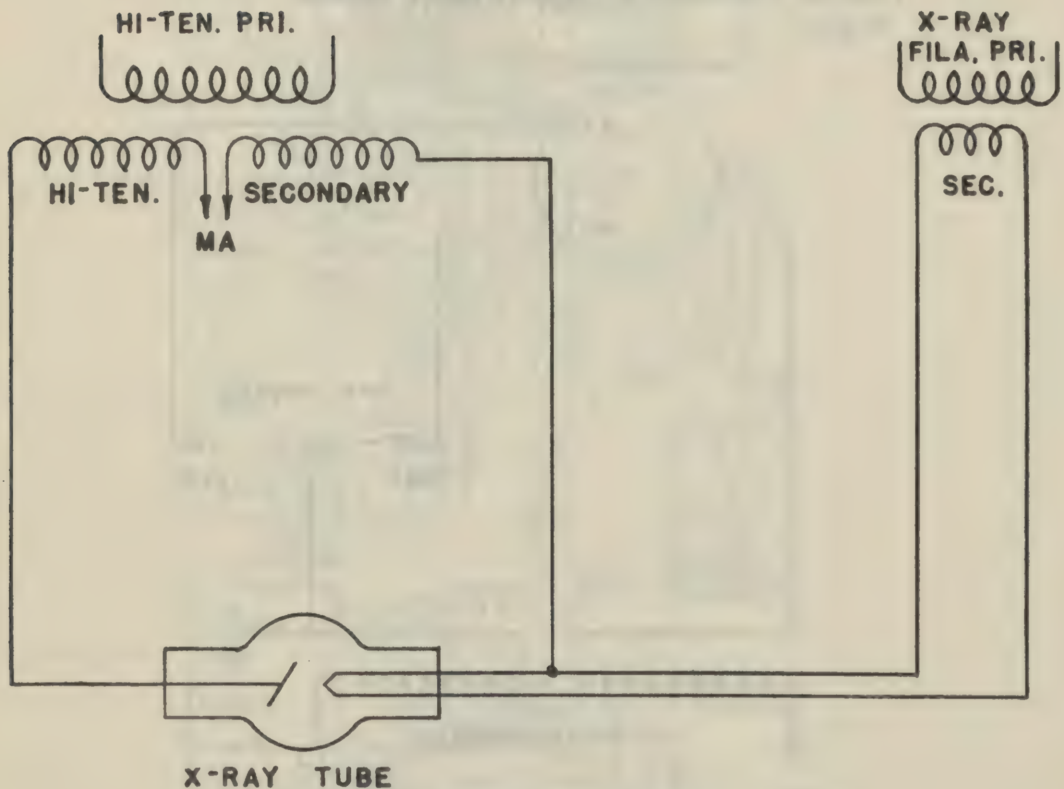
PRIMARY CIRCUIT



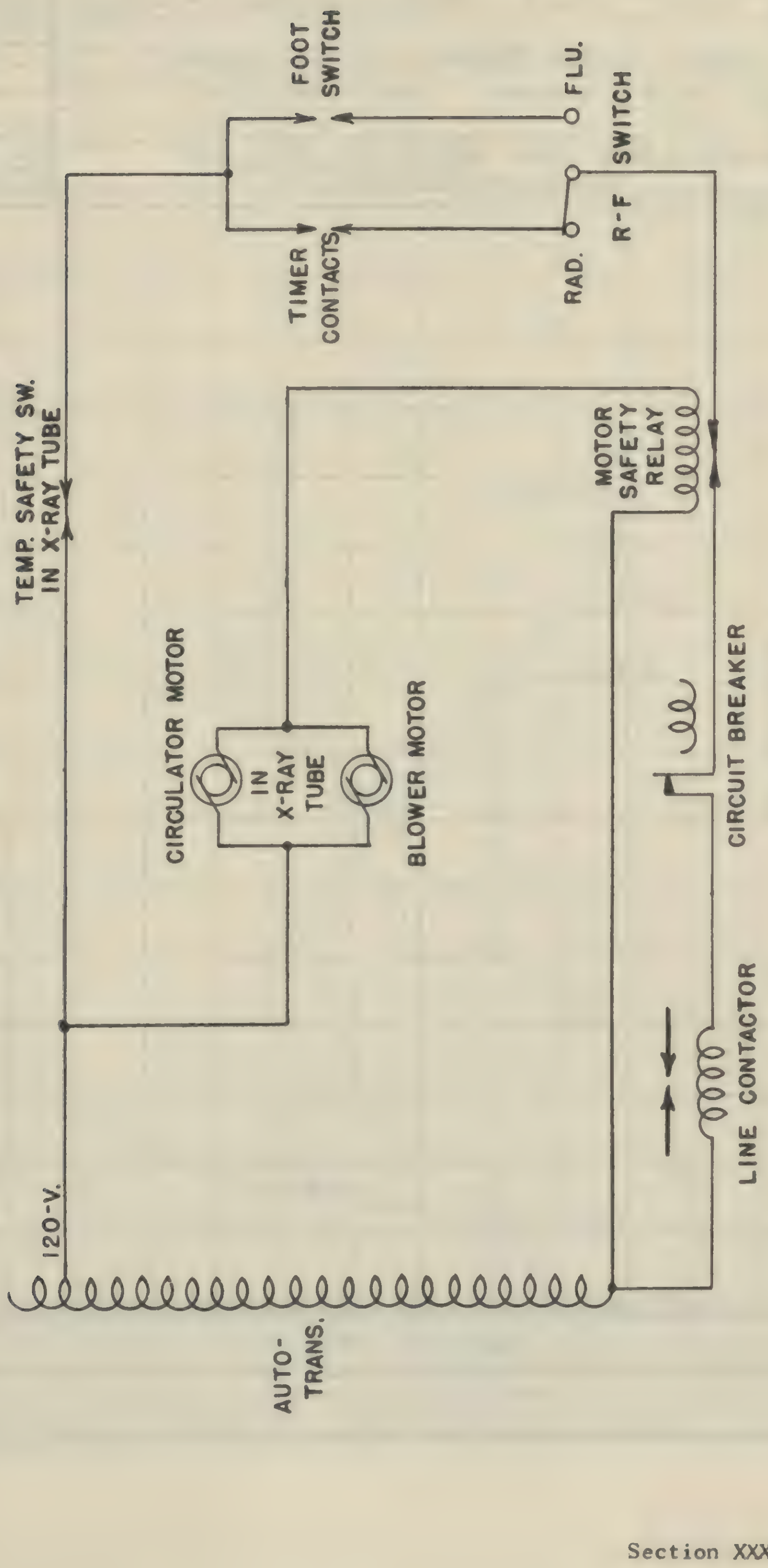
MILLIAMMETER CIRCUIT



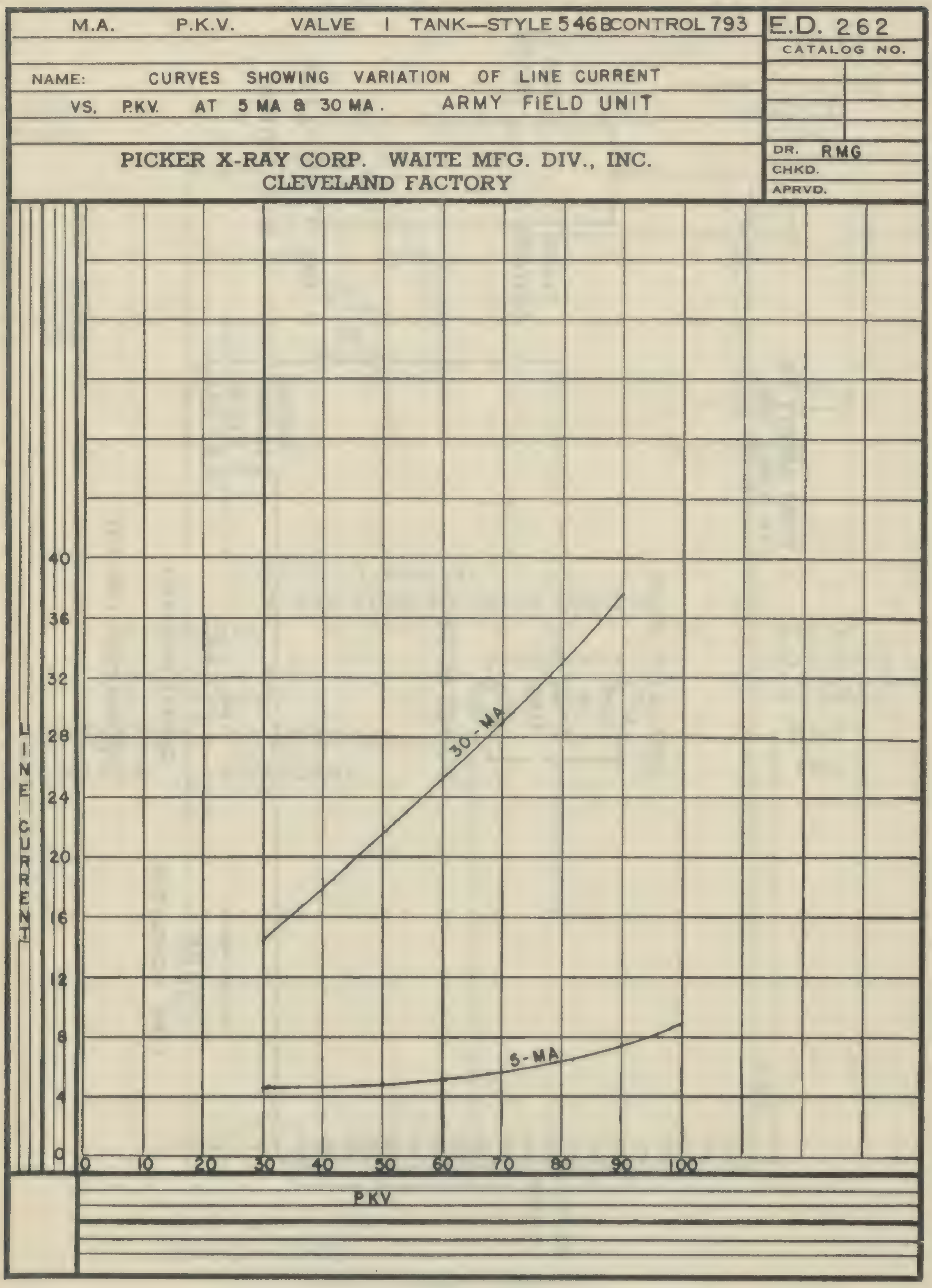
X-RAY TUBE FILAMENT CIRCUIT

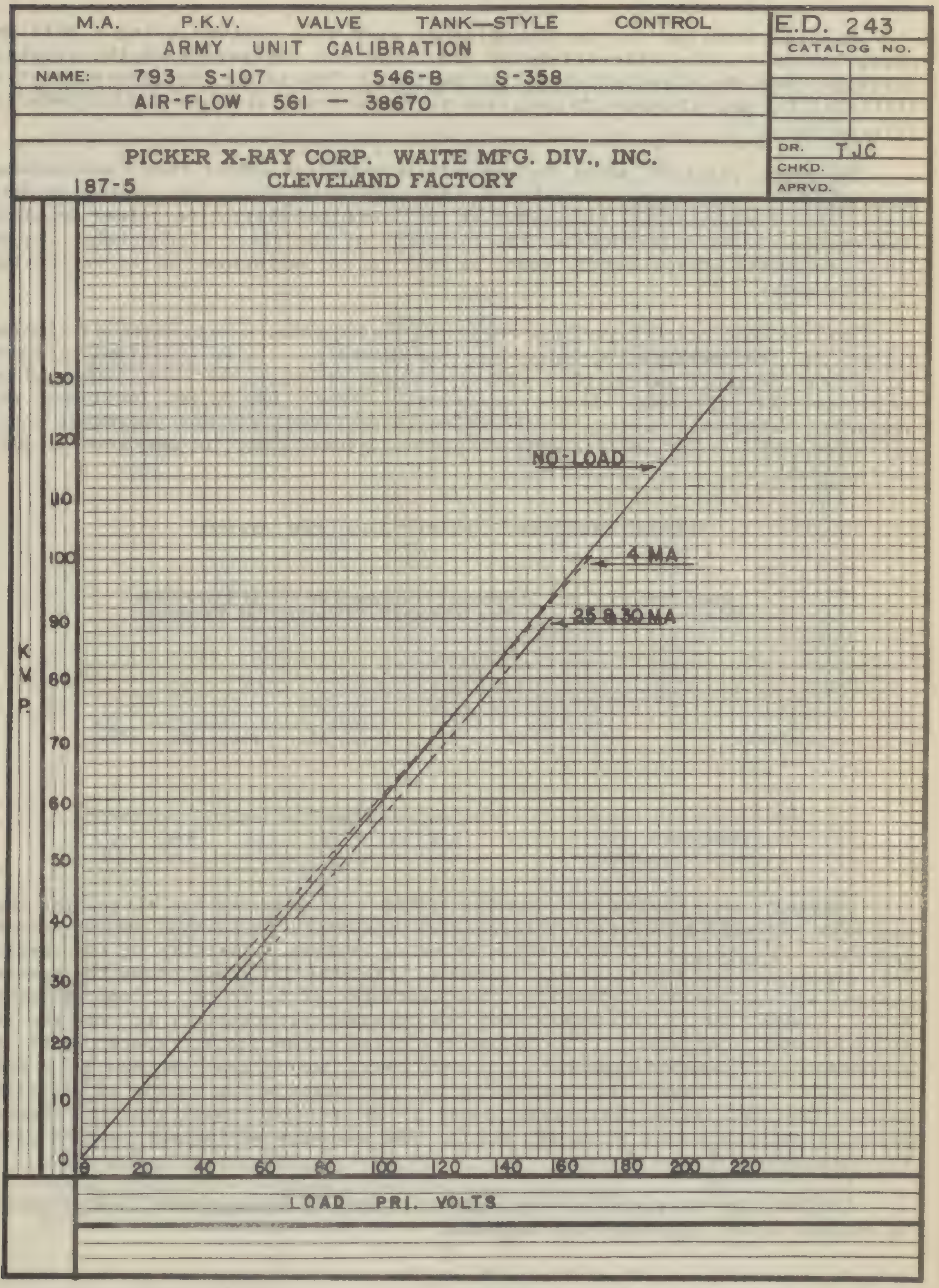


HIGH TENSION CIRCUIT



OPERATING CIRCUIT


M.A. P.K.V. VALVE I TANK—STYLE 546B CONTROL 793
E.D. 262
CATALOG NO.
NAME: CURVES SHOWING VARIATION OF LINE CURRENT
VS. P.K.V. AT 5 MA & 30 MA. ARMY FIELD UNIT
DR. RMG
CHKD.
APRVD.
PICKER X-RAY CORP. WAITE MFG. DIV., INC.
CLEVELAND FACTORY
LINE CURRENT
0
4
8
12
16
20
24
28
32
36
40
30-MA
5-MA
0 10 20 30 40 50 60 70 80 90 100
PKV


M.A. P.K.V. VALVE TANK—STYLE CONTROL
E.D. 243
CATALOG NO.
ARMY UNIT CALIBRATION
NAME: 793 S-107 546-B S-358
AIR-FLOW 561 — 38670
DR. TJC
CHKD.
APRVD.
PICKER X-RAY CORP. WAITE MFG. DIV., INC.
CLEVELAND FACTORY
187-5
K.V.P.
0 10 20 30 40 50 60 70 80 90 100 110 120 130
0 20 40 60 80 100 120 140 160 180 200 220
NO LOAD
4 MA
25 & 30 MA
LOAD PRI. VOLTS

ROENTGENOTHERAPY

Roentgenotherapy can be accomplished with this machine using a milliamperage of four and a kilovoltage of 100. Use the footswitch at the greatest distance from the x-ray tube and the patient. The x-ray tube has a built-in filter of 1/4 mm. aluminum in addition to the 1/2 mm. aluminum filter inherent filtration.

The chart, Figure W, shows the approximate radiation output from these machines when operated under normal conditions. The radiation output may vary from these figures by as much as 20%, especially at the low added filtration values depending upon manufacturing tolerances in the thickness of the glass of the tube, the oil flow between the window and the tube, as well as the variations in the calibration of the machine.

Use the more penetrative beam (produced by 100 P.Kv. - with 3 mm. of aluminum filter) for the treatment of infectious lesions only. If the infection is superficial and does not extend more than 2 or 3 cm. deep to the skin, use a 30 cm. focal spot skin distance. If the infection is deeper, use 50 cm. focal spot skin distance. When this quality of radiation is employed, any one treatment should not exceed 75 R. The initial dose should not exceed 350 R in one week or 600 R in two weeks.

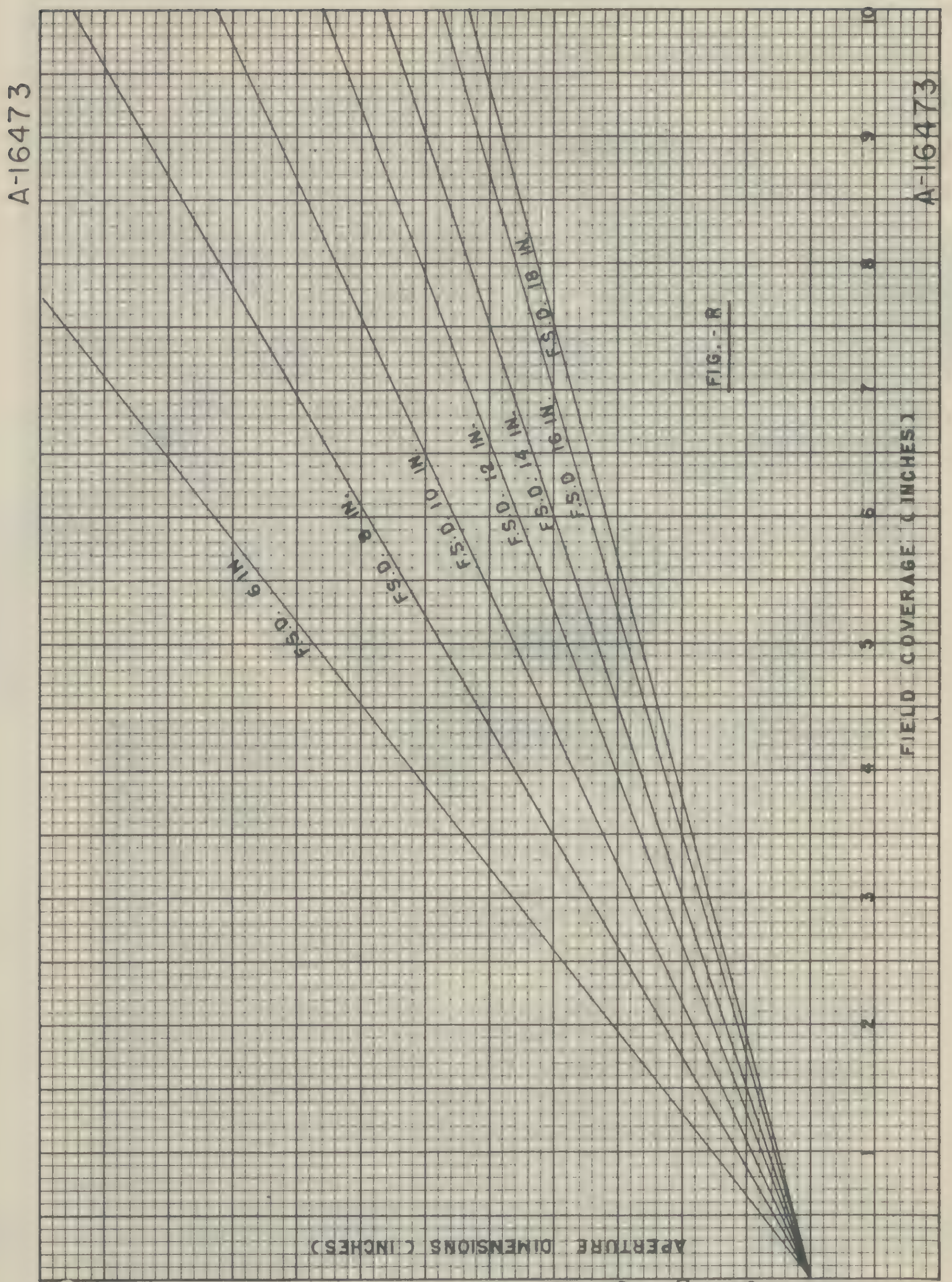
AVERAGE RADIATION OUTPUT IN R PER MINUTE

Focal Spot Skin Distance	Additional Filtration Plus the ¼ Fixed Added Plus Inherent in Millimeters of Aluminum						
	0	¼	½	1	1½	2	3
30 Cm.	72	50	41	31	25	20	16
50 Cm.	25	17	14	11	9	8	6
Half Value Layer in mm. of Aluminum	.73	1.25	1.5	2.0	2.5	2.75	3.2

PREPARATION OF LEAD ALLOY APERTURE PLATES - In order to use plates for therapy work, it will be necessary to provide them with an opening to confine the radiation to the specific area which is being treated. The size of the aperture will depend also on the treatment distance. The chart Figure R shows the coverage plotted against aperture dimensions for distances of 6, 8, 10, 12 and 14 inches. As an example, let it be assumed that the treatment distance is 10" and the area to be treated is 4" x 6". If we follow the curve of 10" F.S.D., the 4" point will correspond to an aperture opening of 15/16", and 6" point to an aperture of 1-3/8". Then by using the cross lines punched in the lead plate as the center of radiation, an aperture the size as determined above, 15/16" x 1-3/8", will give the required field of radiation 4" x 6" at 10" F.S.D. The coverage of the pre-punched plates is indicated in Figure R.

CAUTION: The filter is a very important part of therapy work, and it should be checked before starting each exposure.

As a convenience, Chart Figure S, may be used as a means of quickly changing inches to centimeters, if the techniques used are specified in this system.


A-16473
A-16473
FIG. - R
FIELD COVERAGE (INCHES)
APERTURE DIMENSIONS (INCHES)
F.S.D. 6 IN.
F.S.D. 8 IN.
F.S.D. 10 IN.
F.S.D. 12 IN.
F.S.D. 14 IN.
F.S.D. 16 IN.
F.S.D. 18 IN.
0
.25
.50
.75
1.00
1.25
1.50
1.75
2.00
1
2
3
4
5
6
7
8
9
10

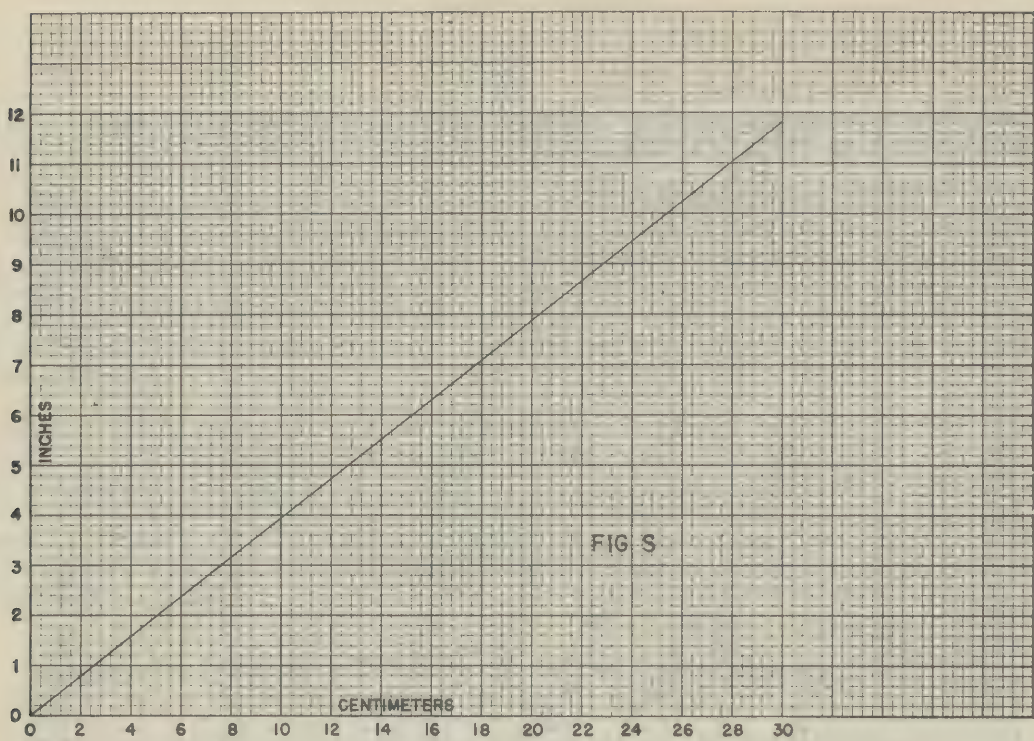


Figure S

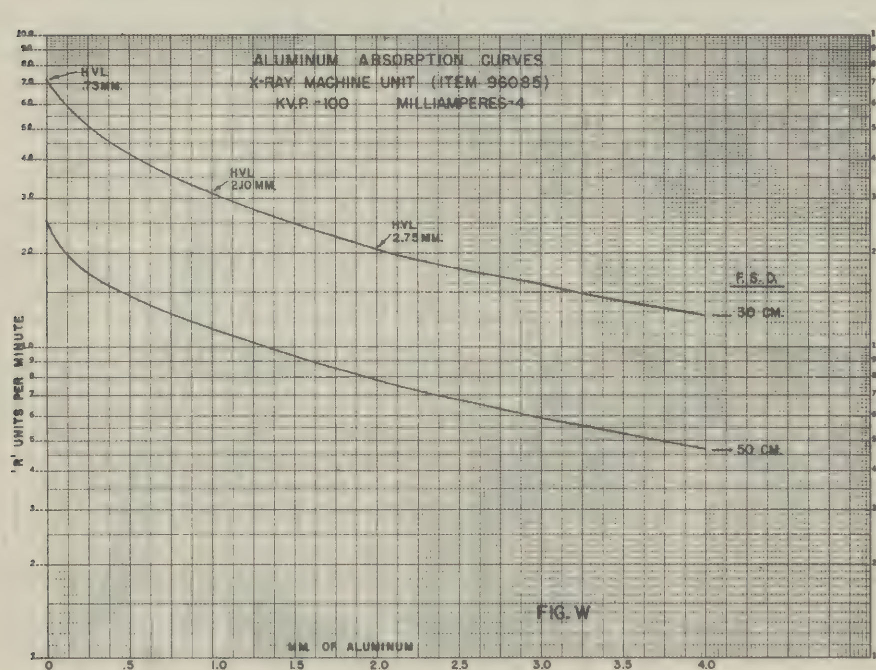


Figure W

Figure I

SPARE CABLE CHEST WITH FIVE CABLES

Figure I shows the method of packing the spare cables in the field chests. There are five of these shockproof high-tension cables packed in each chest. The cables are so packed that any one or more cables may be removed from the chest and shipped separately by express or freight.

It is recommended that the package be carefully studied before the removal of the new cable so that the defective cable may be packed in this same carton and returned to the supply base or to the place from which the replacement cable was received.

TABLE OF WEIGHTS OF EQUIPMENT

		Pounds
Mobile Base Chest X-1	60	
Mobile Base and Tubestand	120	
Chest X-1 — Total weight		180
High Tension Transformer Chest Complete X-2		177
X-ray Tube Chest X-3	72	
X-ray Tube, Cables and Accessories	43	
Chest X-3 — Total weight		115
Control Unit Chest X-4	75	
Control Unit, Footswitch, Hand Timer, Localization Lamps and Cord	91	
Chest X-4 — Total weight		166
Lead Rubber Gloves and Apron, Goggles	14	
Chest X-4, complete with above items		180
Gas Electric Generator	200	
Carrying and Shipping Case with Spare Parts	116	
		316

Dimensions of reinforced plywood chests—
X-1, X-3, X-4, 17½"x 30"x 16" high.

Steel Transformer chest—
X-2, 13½"x 13½"x 23½" high.

POWER TRANSFORMER AND LINE WIRE SIZES

For the proper operation of this U. S. Army mobile field unit, it is imperative that an adequate line or power transformer and a line of suitable wire size be provided.

If the line size or transformer size is less than the values shown below, it may be necessary to reduce the maximum milliamperage values used in order to obtain satisfactory radiographic results. Naturally, if the milliamperage is reduced, the exposure time must be increased to obtain the same milliampere seconds value.

The values shown below are based on a single x-ray machine load only. If there are other loads such as lights, pumps, blowers or heaters, etc., connected, it will be necessary to reduce the x-ray load or to increase the supply transformer or the line size or both.

MAXIMUM MILLIAMPERAGE	MAX. PKV	LINE LOAD		
		VOLTS	AMPS	WATTS
5	85	115	6.4	535
10	85	115	11.2	795
15	85	115	16.9	1150
20	85	115	22.7	1525
25	85	115	29.5	1900
30	85	115	36.0	2250

The above values are based on actual test. If the line voltage is lower than 115 volts, the line amperes will be increased proportionally. If the line voltage is increased, the line amperes will be decreased.

The following table indicates the load that can be carried by the various line wire sizes and supply transformers normally encountered.

Wire Sizes	Supply Transformer in KVA	Maximum Current Rating for Indicated Length of Run in Feet			
		50	100	150	200
14	3	20	10	6.7	5
12	3	25	15	12	8
10	3	30	20	15	12
12	5	30	15	10	7
10	5	40	25	17	10
8	5	50	35	22	15
10	7.5	45	25	18	12
8	7.5	55	30	22	15
6	7.5	70	40	30	20
8	10	60	45	30	20
6	10	75	57	40	30
4	10	90	70	45	40

The above figures based on a 6% allowable voltage drop where voltage drop of transformer is assumed to be 3% or less at full rating. Line volts drop = length of same in feet times 2, times the resistance in ohms per foot, times the maximum current used. The transformer voltage drop which is assumed to be 3% of rated line voltage at full load can be calculated for any load less than 100% by

$$\text{Trans voltage drop} = \frac{\text{Amperes load (less than max. rating)}}{\text{Amperes maximum rating}} \times 3\% \times \text{line voltage}$$

$$\text{where amperes maximum rating} = \frac{\text{KVA nameplate rating} \times 1000}{\text{line voltage}}$$

SECTION XXXIV

FIELD TABLE - W
FOREIGN BODY LOCALIZATION

FIELD TABLE (W) FOREIGN BODY LOCALIZATION

The U.S. Army X-Ray Field Table was built from carefully planned specifications resulting from considerable research by The Department of Roentgenology, Army Medical School. This unit, though very sturdy and rigid, can be dismantled and packed in two field chests. No tools are required to assemble or pack the unit. The apparatus and packing fittings are designed so that the parts cannot become lost or loosened during transport or operation.

Numerous applications are made possible by employing the Multiplane arm design, where the fluoroscopic screen and x-ray tube are mounted on a C-shaped tubular frame at a fixed distance from each other. This C-shaped member can be rotated in a vertical and horizontal plane, or raised and lowered by using the two crank handles and the free rotation around the vertical column.

The various set-ups obtainable are:

Horizontal fluoroscopy; Foreign body localization.

Vertical fluoroscopy with patient in a sitting position on the table.

Vertical fluoroscopy with patient standing upright.

Horizontal radiography over table.

Horizontal six foot chest radiography and vertical G.I. studies at shorter distances.

For protection of the patient a ½ mm. aluminum filter and a fluoroscopic guard are provided. The aluminum filter is part of the shutter housing and should never be removed.

The fluoroscopic guard is different from the conventional type. It is constructed of a U-shaped steel bar which falls into place by gravity when the unit is used for vertical fluoroscopy. Since the guard is collapsible it is not necessary to remove it when the x-ray tube is under the table.

TABLE PARTS

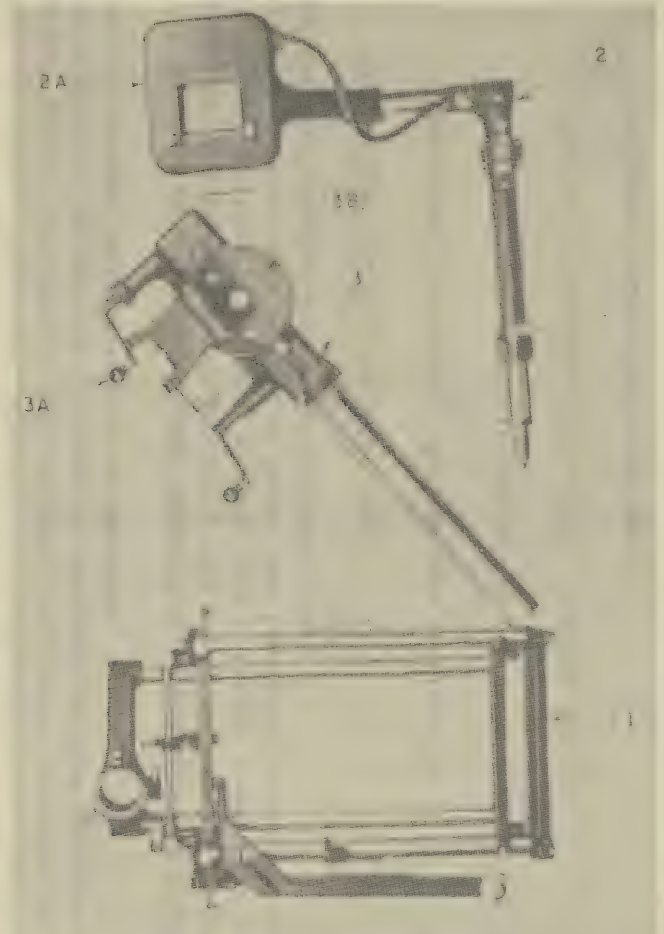


FIG 1

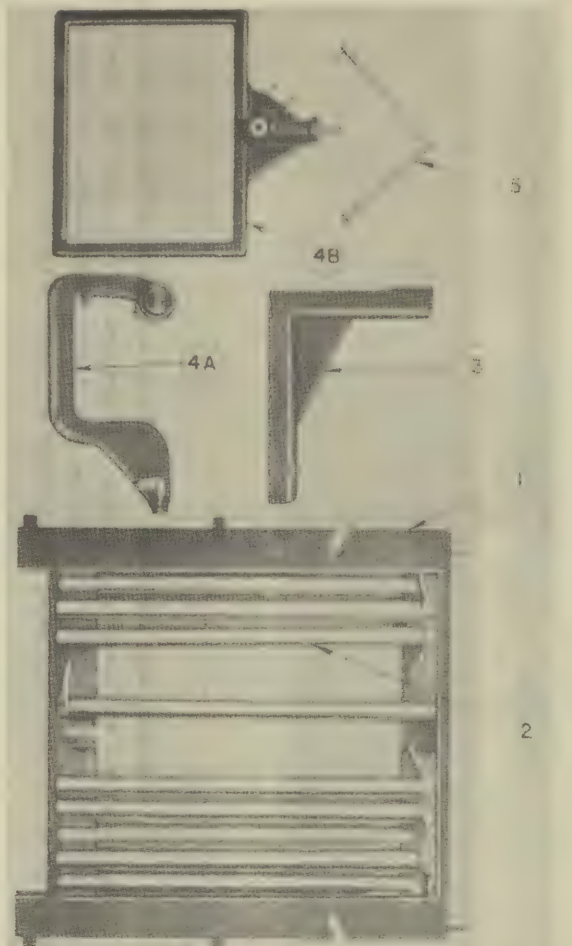


FIG. 2

The complete table consists of the items shown in Fig. 1 and Fig. 2.
(1) Horizontal carriage, including linear scale.
(2) L-shaped member, including shutter and shutter control.
(3) Adjustable vertical column.

(1) 2 Table end supports.
(2) 9 Knock down rails
(3) 2 Table leg extensions.
(4A) 1 Fluoroscopic screen arm.
(4B) 1 Fluoroscopic screen.
(5) 1 Depth scale member and marker.

ASSEMBLY OF UNIT

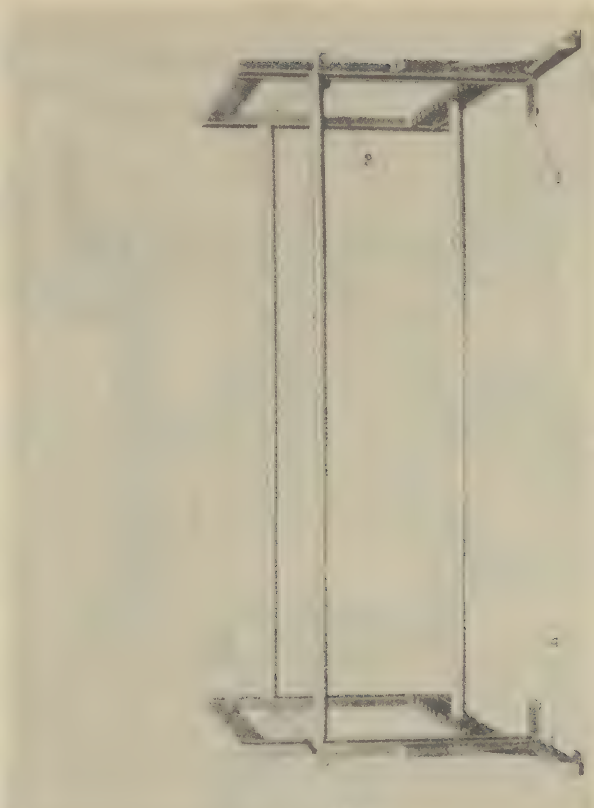


FIG. 4

Assemble the rail sections to make three complete rails and place in cut-outs (1) in table end supports. Be sure that the rails extend into the recesses (2) bored in the cut-outs, and that the hinged floor plates (3) are in the correct positions.

Raise the end supports and slide the leg extensions (4) into position on operating side of table.

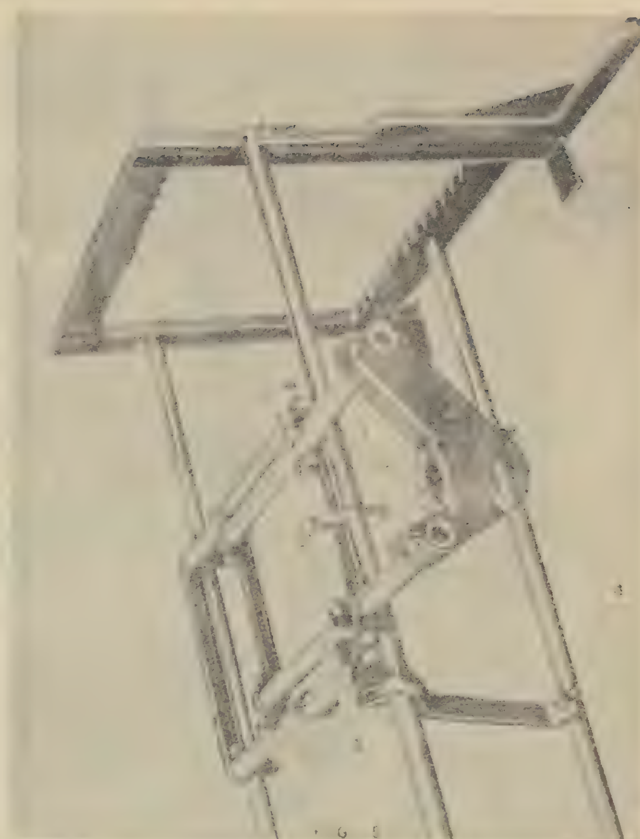


FIG. 5

First place the horizontal carriage on the top rails, positioning the rear bearings on rail, then lower front into position. Be sure that pointer screw (1) is loose so lock arm (2) clears rail, that lock clamp (3) is in position, and that bearing of support (4) is on lower rail.

ASSEMBLY OF UNIT

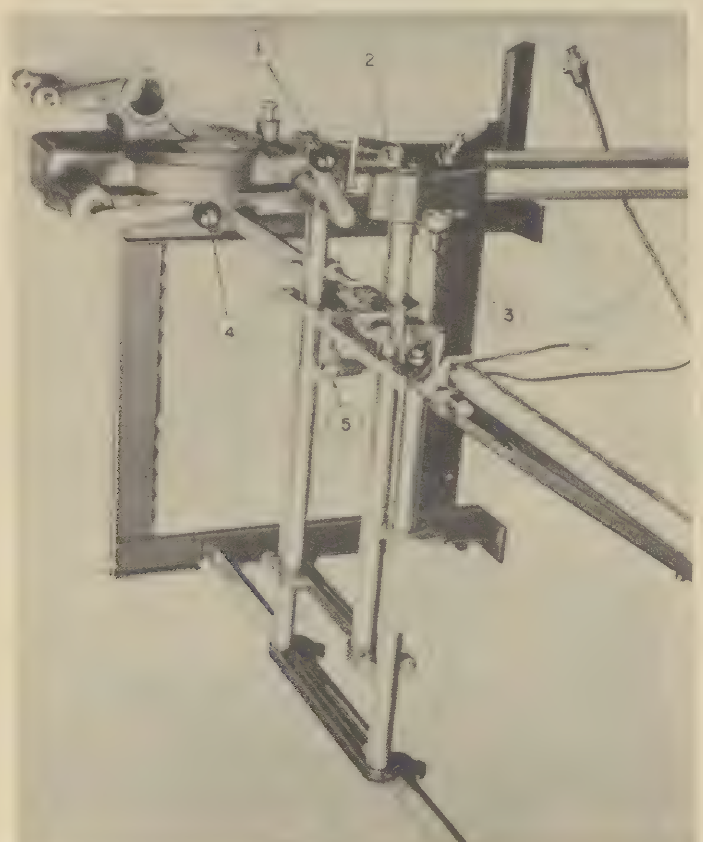


FIG. 6

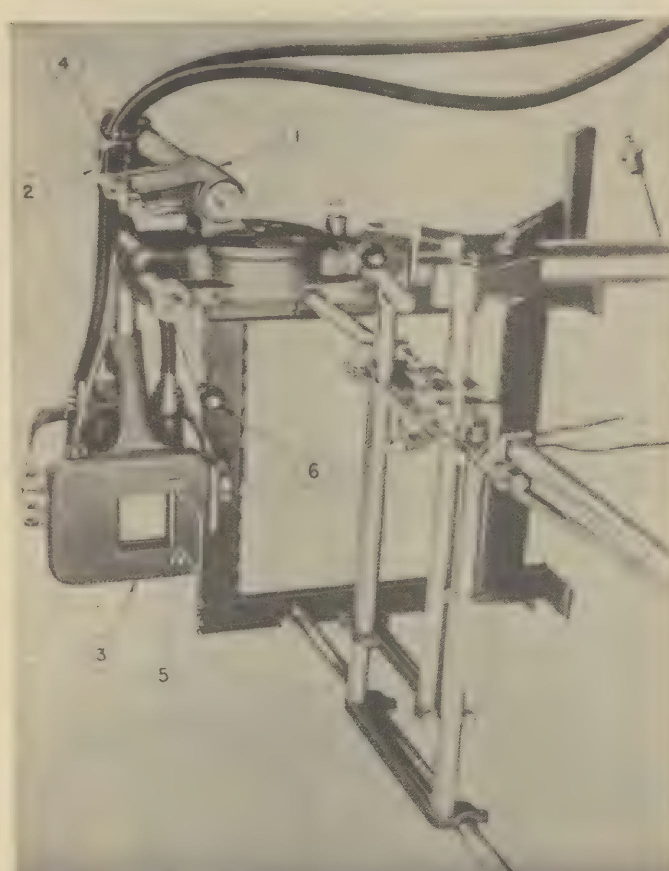


FIG. 7

Turn crank (1) of adjustable vertical column until flange (2) coincides with black line on column. Insert column down into hole in casting so key on flange is in slot on rear of casting. Tighten lock (3). Turn crank (4) so main bearing is turned to position shown.

Insert L-shaped member into hole in bearing casting (1) and tighten lock (2). Rotate shutter (3) to correct position. Insert x-ray tube yoke at end of arm and lock in position. Loosen lock screw (4), insert shockproof cable in cut-outs and clamp in position.

ASSEMBLY OF UNIT

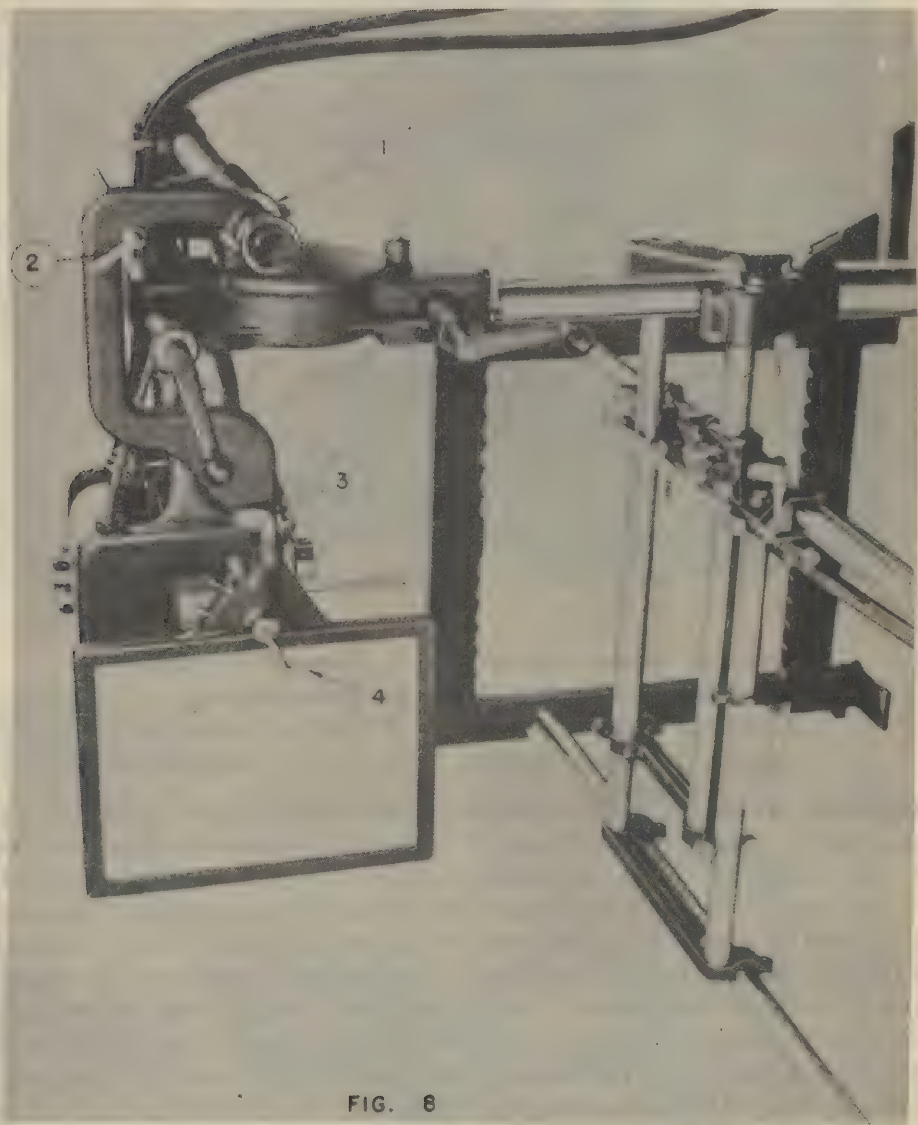
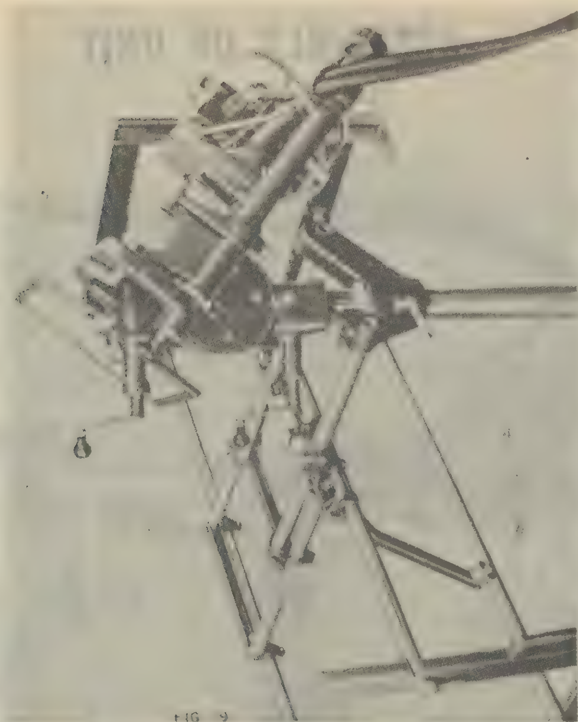


FIG. 8

Mount fluoroscopic screen arm, and tighten ring nut (1). Swing arm into position and secure with lock lever (2). Insert fluoroscopic screen assembly and tighten lock lever (3). Turn handle (4) of depth scale member and marker, insert through screen frame, as shown.



1. Lock for vertical adjustment
2. Crank for vertical adjustment
3. Crank for vertical rotation
4. Lock for horizontal rotation
5. Fluoroscopic guard
6. Shutter housing
7. Lock for transverse travel
8. Lock for longitudinal travel

OPERATION OF UNIT - Before operating the x-ray field table, it is necessary to become familiar with the controls of this unit, especially the two crank handles (2) and (3) figure 9. These two crank handles are part of the adjustable vertical column. Turning crank (2) raises and lowers the Multiplane arm. Turning crank (3) rotates the Multiplane arm in the vertical plane. To rotate the tube and screen in the horizontal plane, loosen lock (4). The assembly can then be swung about the long axis of the vertical column. Operating crank (2) adjusts the Multiplane arm to the height or thickness of the patient during fluoroscopy, or to obtain the desired tube-film distances in radiographic work. Operating crank (3) is only necessary when changing to a different set-up of the unit.

To rotate from horizontal to vertical fluoroscopy, or vice versa, loosen lock (1) and adjust crank (2) to black mark on column. Swing tube and screen assembly about vertical column until arrow on instruction plate points to center of table. Move column out from table to extreme end of transverse travel. Turn crank (3) to turn tubehead to desired position.

Figure 9, illustrates an intermediate position during the adjustment of crank (3).

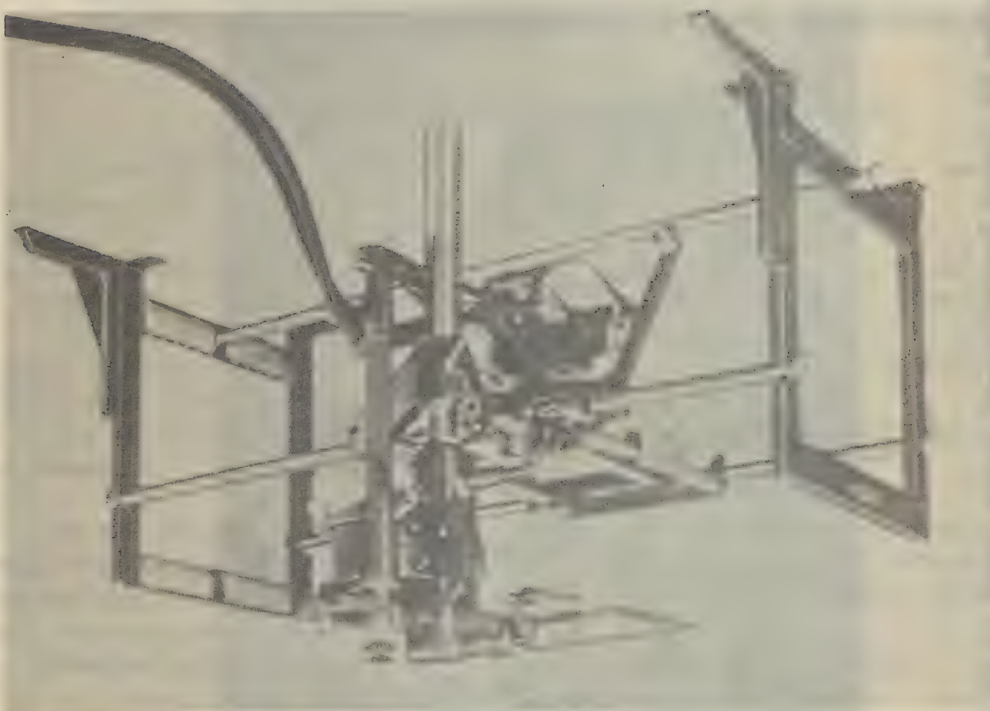
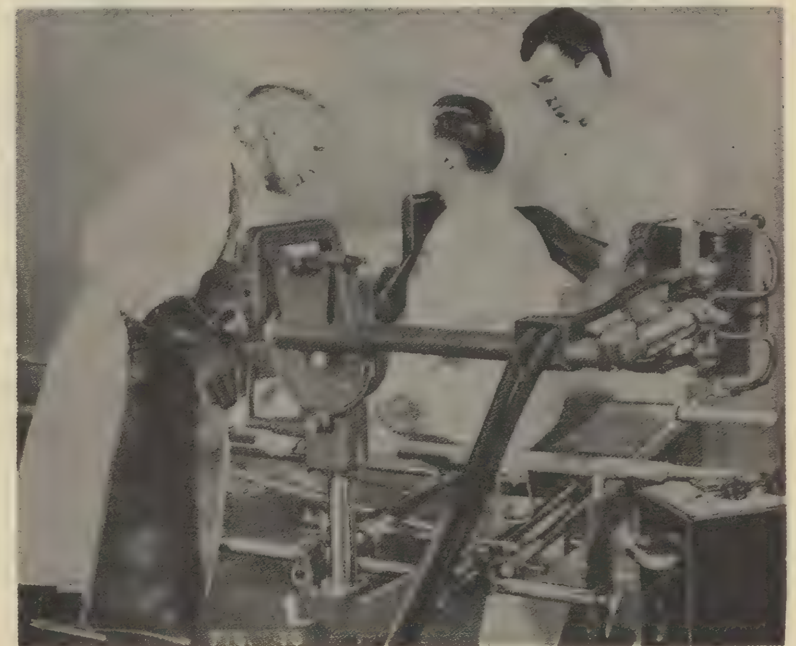


FIG. 10

Table completely assembled for horizontal fluoroscopy with depth scale and marker in place for foreign body localization.

Position for horizontal fluoroscopy and foreign body localization.

Position for vertical fluoroscopy with patient standing on the floor. Fluoroscopic guard (5), Fig. 9, page 6, should project at a 90° angle from the shutter plane against patient during fluoroscopic examination, and the shutter (6) moved into position in front of the tube aperture.



Position for vertical fluoroscopy with patient sitting on the litter; also note Fig. 8, page 5. To place patient in position, open lock lever (2) and swing screen and screen arm about pivot (1); and bring screen to original position after patient is in place. Be sure to use fluoroscopic guard when fluoroscoping.

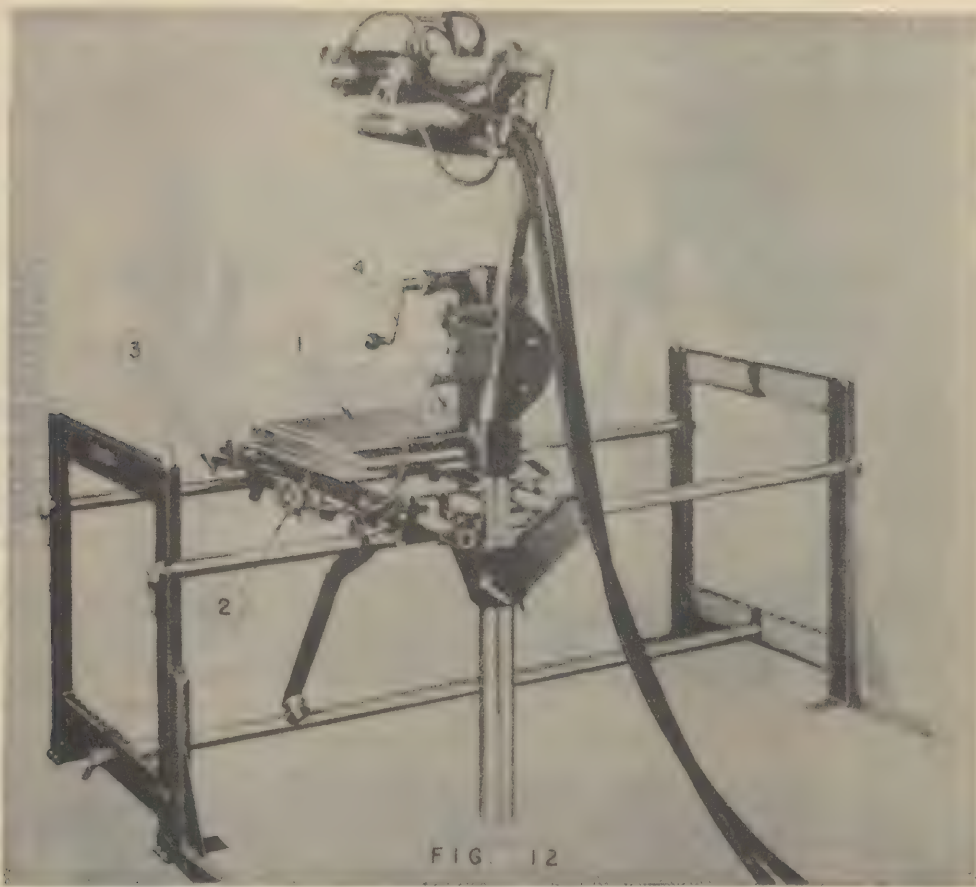


Table completely assembled for horizontal radiography.

CHANGE FROM FLUOROSCOPY TO RADIOGRAPHY - When changing from fluoroscopic to radiographic set-up, the following steps must be taken:

(A) Bring Multiplane arm in position as far vertical fluoroscopy. Figure 8.
(B) Remove fluoroscopic screen by loosening lock lever (3). Figure 8.
(C) Loosen lock lever (2), figure 8, remove screen arm by swinging it away from lock lever (2) and unscrewing ring nut (1). This operation produces the set-up illustrated in Figure 7.
(D) Turn crank (6), figure 6, until the x-ray tube is in the position as shown in figure 12.

To install the special U.S. Army wafer grid, if supplied proceed as follows: Place the diaphragm (1) Figure 12, in position on the horizontal carriage and swing the catches (2) to engage the lock pins. The crank (3) is used to raise or lower the diaphragm to accommodate patients of varying weight. The grid may be removed by releasing spring clip (4) and used separately for portable work.

When the wafer grid is used for radiographic work, the x-ray tube must be centered with the grid. This can be accomplished by angulating the L-shaped tube arm. The shutter housing must be moved to clear the x-ray tube.

HORIZONTAL SIX FOOT CHEST RADIOGRAPHY

FIG 13

Position for horizontal six foot chest radiography with patient on litter on the floor. Note position of shutter housing.

VERTICAL SIX FOOT CHEST RADIOGRAPHY

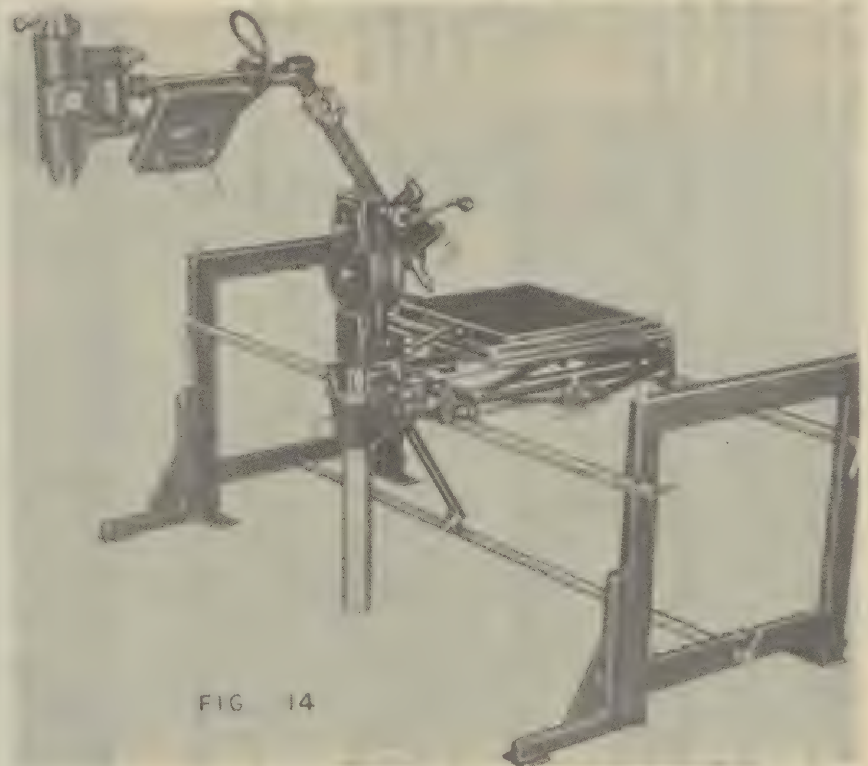
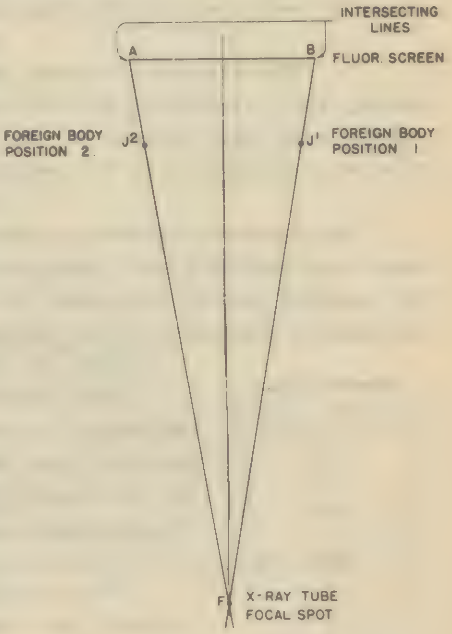


FIG 14

Position for vertical six foot chest radiography and vertical G. I. studies at shorter distances. Figure 14 shows how the x-ray tube can be positioned for vertical radiography. The flexibility of the unit makes it possible to obtain other suitable positions for this type of work, depending on the set-up of equipment and the location of the special cassette holders.

FOREIGN BODY LOCALIZATION - A linear scale mounted on the horizontal carriage of the table, three equally spaced lines on the fluoroscopic screen (outer lines 22 cm apart) and a depth marker mounted on the fluoroscopic screen are the main parts necessary for foreign body localization.

The fluoroscopic screen and the x-ray tube are mounted rigidly on the same frame work and move as one unit. The x-ray tube is at all times centered with the fluoroscopic screen.



Two imaginary thin pencils of rays out of the cone of x-radiation striking the fluoroscopic screen will coincide with the two outer intersecting lines on the fluoroscopic screen and form the sides of a triangle, with the fluoroscopic screen as its base and the focal spot of the x-ray tube as its apex.

If a foreign body is moved into the path of one of these pencils of x-rays, it will cast a shadow on the fluoroscopic screen at one of the intersecting lines on the screen. The further the foreign body is away from the fluoroscopic screen the less travel of the screen and tube assembly is needed to move the shadow of the foreign body from one intersecting line to the other. The amount of travel necessary is in direct relation to the depth of the foreign body below the screen.

Considering the diagram showing geometric details:

1. A-B equals spacing between outer intersecting lines on screen. It is equal to 22 cms.

2. F-S equals focal-screen distance (focal spot to intersection of central intersecting lines). It is equal to three times A-B, or 66 cms. (plus or minus minor deviations in the position of the focal-spot.)

3. If a foreign body were located at S (i.e., just beneath the intersection of the central intersecting lines), for alignments of it to the intersection of the outer intersecting lines at A and then at B, the x-ray tube would have to be moved with the fluoroscopic screen a distance equal to C-D. C-D equals A-B (i.e., 22 cms.). In the case of foreign bodies located at other levels below the plane A-B, the same ratio relationship would hold: that is, the range of travel of the x-ray tube and fluoroscopic screen for the alignments of the foreign body with points A and B respectively, would be 1/3 the distance F-J. J-1 is the foreign body location with tube-screen position as shown in diagram B, J-2 as in diagram C. F-B parallel to E-I, F-A parallel to G-H.

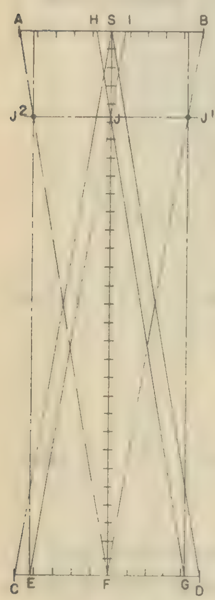
4. Since triangle E-J-G is similar to triangle J-H-I, the distance S-J bears the same ratio relationship to H-I as does J-F to E-G; that is, a three to one ratio.

5. H-I is equal to H-S plus S-I.

6. H-S equals G-D while S-I equals C-E; therefore, H-I equals C-E plus G-D; C-E plus G-D is the untraveled distance (22 cms. minus the distance of travel) which actually measures the location of the foreign body beneath the fluoroscopic screen.

7. The distance between the fluoroscopic screen to the skin is subtracted by making the adjustment of the pointer to an "Arbitrary Zero" as shown in diagram B and thereby the reading of the untraveled distance (as indicated on the localization scale) indicates the measurement of the foreign body beneath the skin level.

The distance between x-ray tube and screen is fixed. This automatically eliminates one variable and makes possible direct reading for foreign body localization. The special scale, provided for this purpose, is mounted in a sliding frame on the horizontal carriage of the table. See drawing on page 13.



GEOMETRIC DETAILS

This scale is provided to indicate *the difference* of travel necessary to move the outlines of the foreign body from one intersecting line on the fluoroscopic screen to the other, as compared to the travel necessary if the foreign body were touching the fluoroscopic screen.

The further away the foreign body is from the fluoroscopic screen, the less travel of the fluoroscopic unit will be needed.

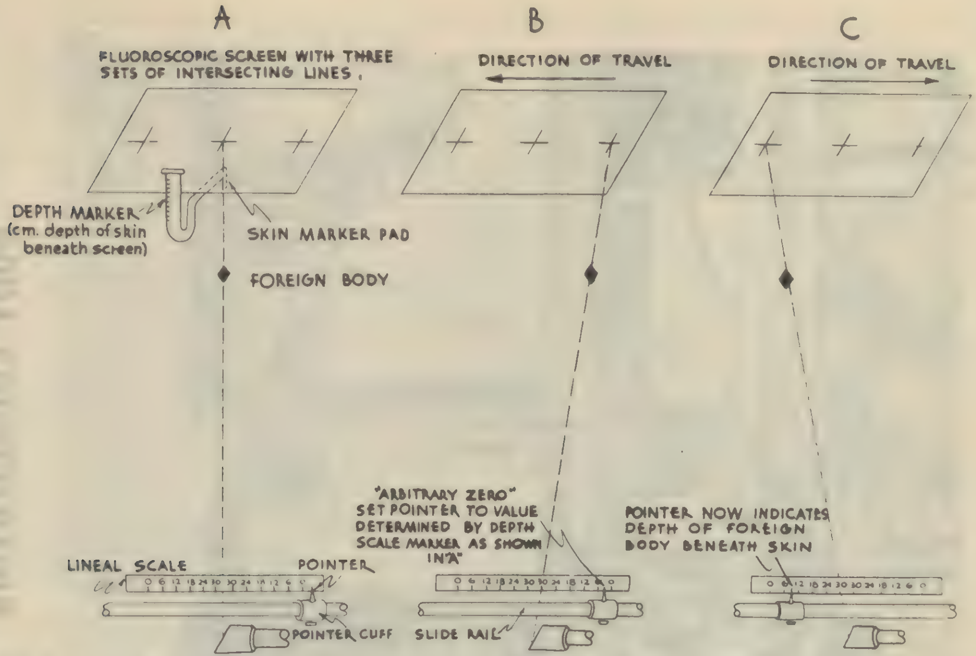
This special scale starts with zero at both ends and reads toward the center, each scale ending at the 33 cm. mark. Readings above this 33 cm. mark are unnecessary, since only locations above the table top are of interest.

Since the design is such that it reads the distance of the foreign body below the screen, it is necessary to subtract the screen-skin distance from the reading of the scale. The screen-skin distance is measured with the help of the depth marker, mounted on the screen frame. This subtraction is easily made as the scale starts at zero from both ends. The adjustable pointer is clamped to the table rail at the centimeter reading corresponding with the screen-skin distance, after the foreign body shadow is lined up with one outside intersecting line on the screen.

Since the scale moves with the fluoroscopic carriage and the pointer stays at its fixed position, the amount of travel necessary to line up the foreign body shadow with the other intersecting line on the screen is automatically subtracted. The depth of the foreign body can be read directly after the alignment has been made.

Scale lights, including the necessary cable, are provided for illumination of the depth scale and the linear scale. Figure 22. The light fixture for the depth scale slides on two split pins on the screen frame. The light fixture for the linear scale is clamped with a thumb screw to a bracket on the carriage below the table top. These light fixtures are packed with the x-ray tube.

FIELD TABLE (W) FOREIGN BODY LOCALIZATION



TO LOCATE FOREIGN BODY PROCEED AS FOLLOWS:

1. Check fixation locks on "C-shaped" member; secure alignment of focal spot to center of fluoroscopic screen.

2. Align a prominence on foreign body to intersection of central intersecting lines.

3. Dampen skin marker pad with tincture of iodine or ink and adjust it to this alignment (foreign body and intersection of central intersecting lines). Lower skin marker pad, until it rests on the skin, thereby marking it.

4. Read distance between fluoroscopic screen and skin by way of scale on depth marker (Figure "A").

5. Shift tube and fluoroscopic screen so as to align the same prominence of the foreign body, as considered in Step #2, to the intersection of either of the outer intersecting lines (Figure "B").

6. Slide localization scale and adjust pointer to the centimeter value coinciding with the centimeter distance between the fluoroscopic screen and the skin as measured in Step #4, above. Clamp cuff for fixation of pointer to the side of rail of table.

7. Slide x-ray tube and fluoroscopic screen in direction opposite to that used in Step #5, above, until the same prominence on the foreign body becomes aligned to the intersection of the opposite outer intersecting lines. (Figure "C").

8. Read the depth of foreign body beneath the skin on localization scale.

INSTRUMENTS FOR FOREIGN BODY LOCALIZATION

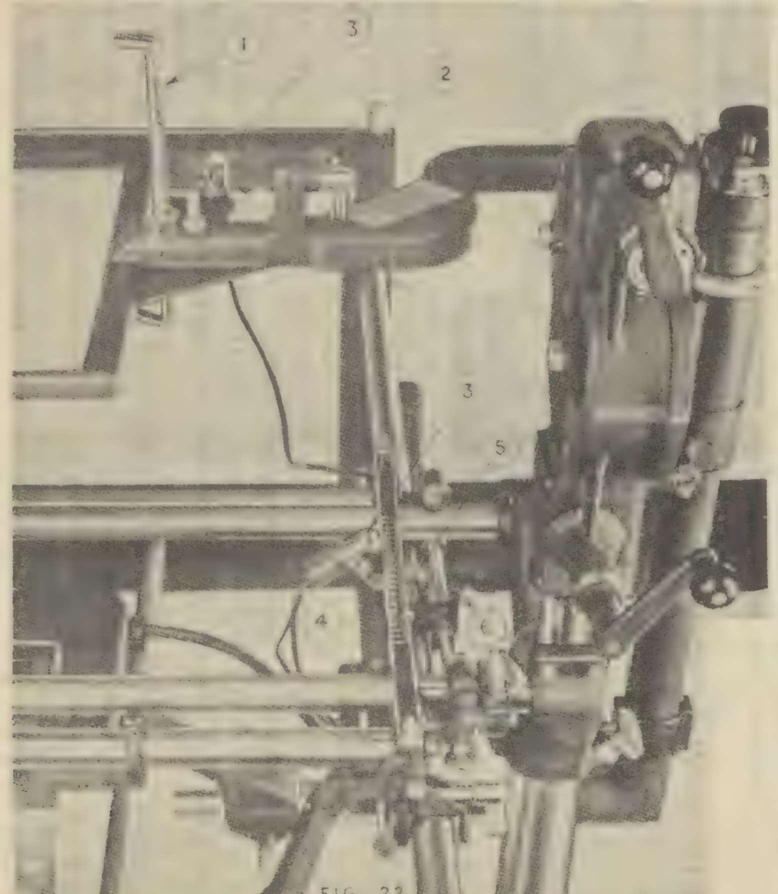


FIG 22

1. Depth scale and marker
2. Adjustable pointer for depth scale
3. Scale lights (2)
4. Linear scale
5. Pointer for linear scale
6. Pointer lock

CHECKING ACCURACY

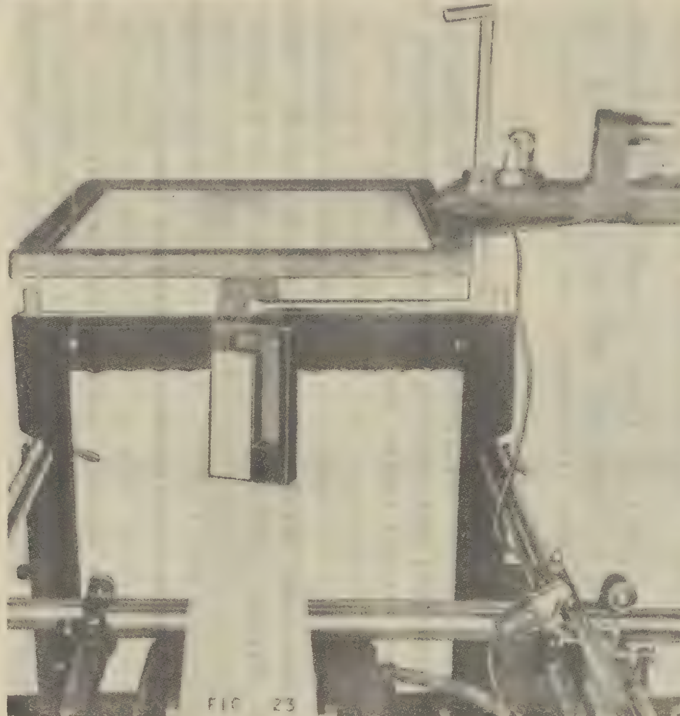
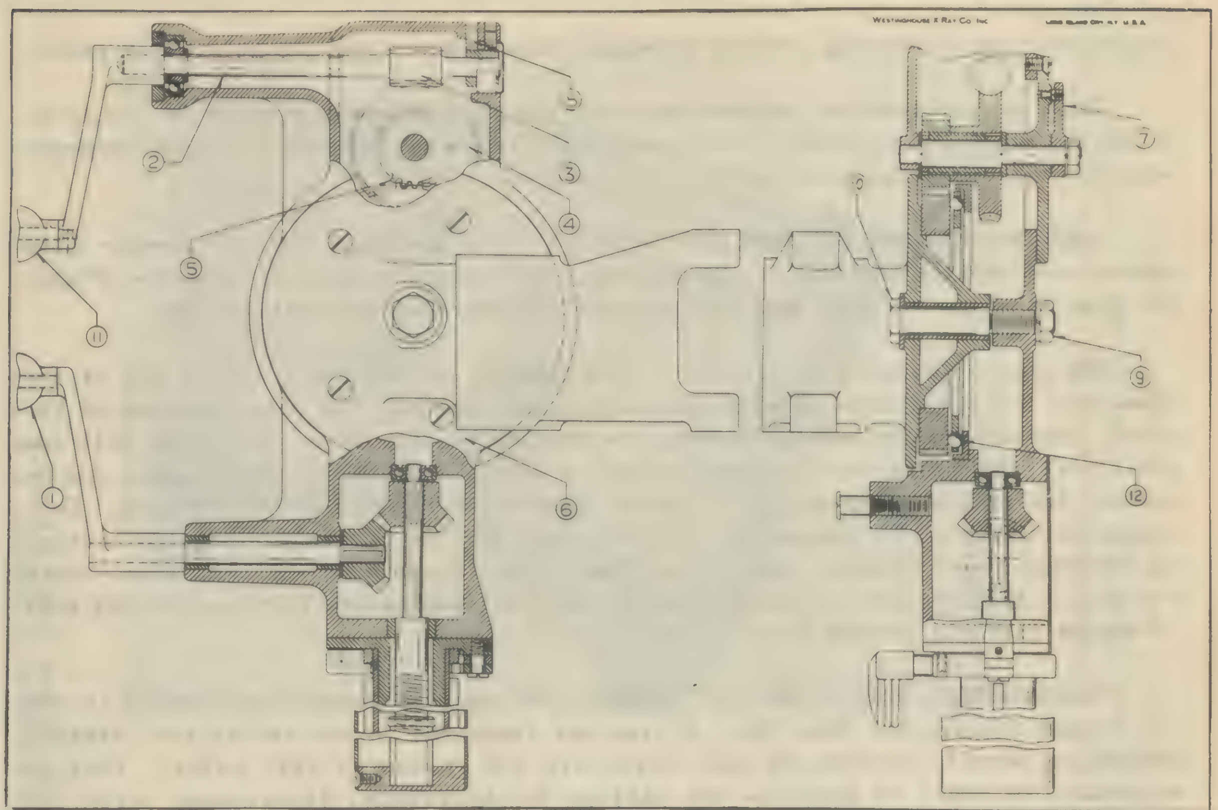


FIG 23

A depth phantom is supplied with the x-ray table and packed with the tools in chest one. This depth phantom is made of wood and has lead numbers imbedded at 3 and 12 cms. depth. When the unit is assembled for the first time, and before proceeding with the localization of a foreign body, place this phantom on a rigid support on the table. Then check to see if the depth measurements, located with x-ray as outlined on page 13, corresponds with the actual location of the lead numbers. If indicated, adjust reading level on depth scale marker. This level is adjustable to provide for variations in the position of the focal spots of one or another x-ray tube.

This check with the phantom is to be repeated if a new x-ray tube is installed or if for any reason the accuracy of the localization is in question.



The adjustable vertical column consists of two telescopic tubings, a crank operated bearing for vertical rotation, and a common hearing for horizontal rotation.

The telescopy of the tubing is accomplished by cranking handle (1). The construction of this mechanism is similar to that of an automobile jack.

The vertical rotation is accomplished by cranking handle (11) which controls a self-locking worm gear drive.

Fastened to the crank shaft (2) is a worm (3) which engages a worm gear (4). Locked to the worm gear and on the same shaft is a spur gear (5) which engages a ring gear fastened to the rotating disc (6). The C-shaped screen and x-ray tube supporting structure is mounted on this rotating disc. Any play in the meshing of the gears can be taken up on the outside of the assembly in the following manner:

The worm gear and spur gear are mounted on a common shaft which has eccentric bearings. Closer mesh of the spur gear with the ring gear can be obtained by adjusting the lever (7) on the rotating bearing casting to a different notch. Then the set-screws (8) on top of the casting are tightened until close contact between worm and worm gear is obtained.

If, due to wear on the bearings, excess play develops in the rotating disc (6), it may be corrected by loosening lock nut (9), turning bolt (10)* clockwise until

*A special wrench is provided for bolt (10) and packed with the tools in chest #1.

proper contact of bearing (12) is obtained, then tighten nut (9) to lock in place.

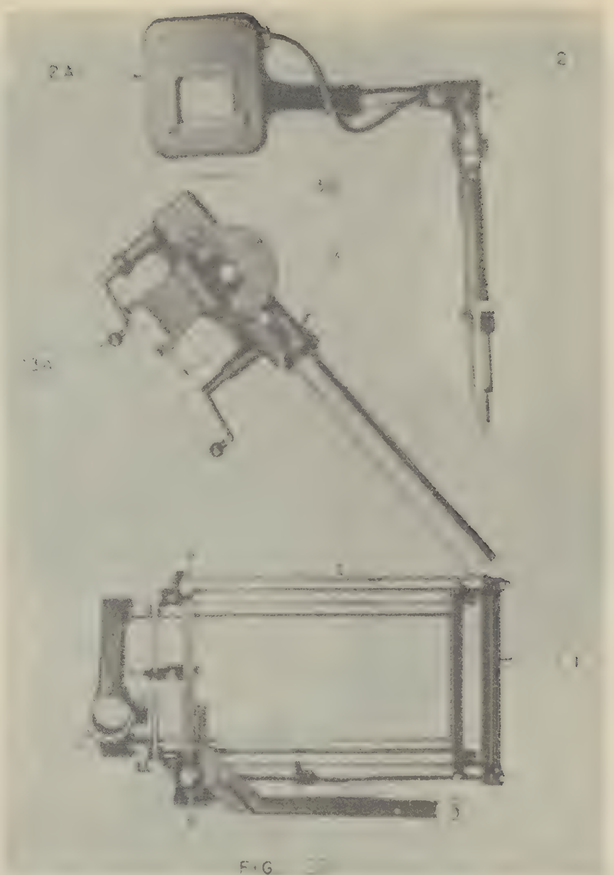
These adjustments are seldom required, but if necessary, great care should be exercised when making them. It is especially important to make these adjustments with the tube and screen removed.

SHUTTER HOUSING AND SHUTTER CONTROLS - The L-shaped tubular member with shutter and shutter controls (Figure 30) and the screen arm and shutter knobs (Figure 31, Item 4A) form one unit when mounted on the adjustable vertical column.

The shutter housing is clamped to the tubular arm and can be moved out of the beam when the x-ray tube is used for radiographic work. Two short lengths of key steel, fastened to the tubing, prevent the shutter housing from rotating at both end positions. The center part of the key-way is cut so that the shutter housing can be rotated for packing purposes. The shutter control is formed of wire and rods. Care should be taken not to damage the wire controls for the shutter. They are encased in flexible steel tubings, covered with neoprene. Rough handling can damage these controls. The two rods extending through the steel tubing are flattened on the ends to engage with the shutter knobs.

FLUOROSCOPIC SCREEN ARM AND SCREEN - The shutter knobs are mounted in the screen arm (Figure 31, Item 4A). A ring nut locks the screen arm to the L-shaped member to permit rotation of the screen arm and screen at this point. This is necessary in order to position the patient for horizontal fluoroscopy with the screen swung out of the way. A black cover is provided to protect the fluoroscopic screen against sun light.

PACKING INSTRUCTIONS CHEST # 1



F·G

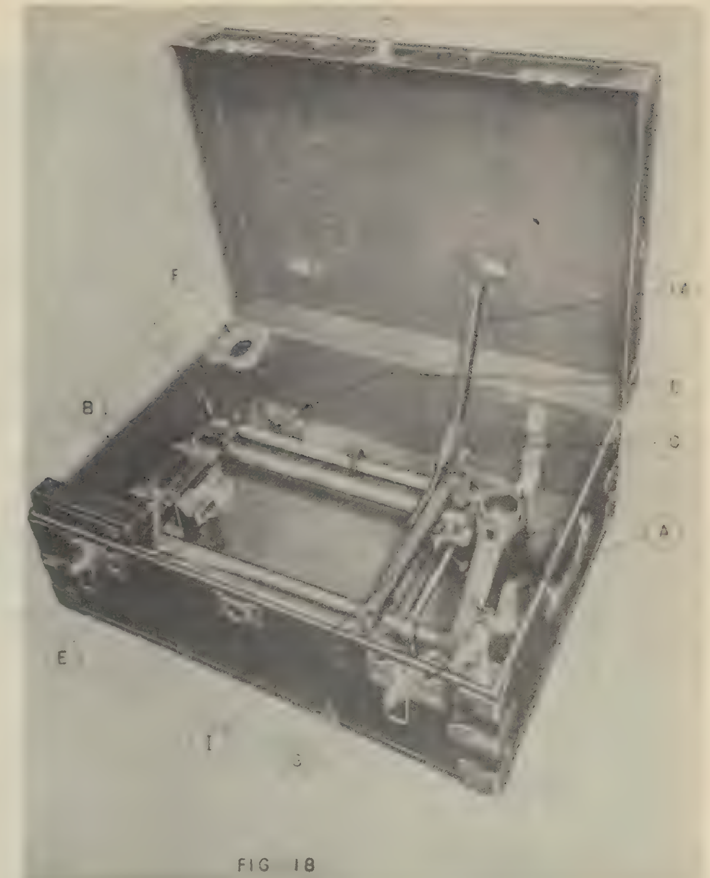


FIG 18

(1) One horizontal carriage including one adjustable linear scale and pointer mounting. (2) One L-shaped member, including fluoroscopic shutters, shutter control and x-ray tube mounting. (3) One adjustable vertical column.

Slide V-shaped casting of horizontal carriage (1) over tubular post (A) and tighten lock (I). Lock opposite end of carriage with two clamps (B). Raise arm (1A) upright as shown.

PACKING INSTRUCTIONS CHEST # 1

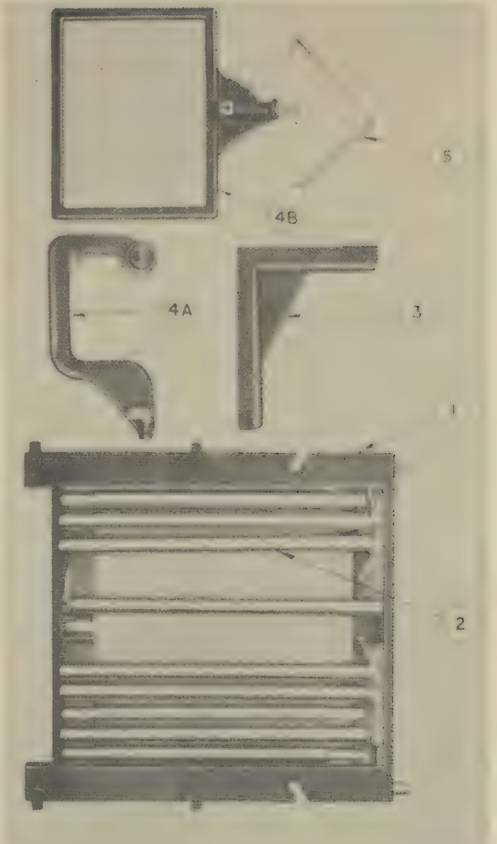
FIG 19

FIG. 20

Turn shutter housing (2A) 90° from normal position—see Fig. 1, page 31. Lock L-shaped member (2) with clamps (C) and straps (D) and (E).

Turn crank (3A) so circular bearing (3B) is 180° from normal position—see Fig. 1. Slide vertical column (3) into supporting sleeve (F) and lock with clamp (G). Lower arm (1A) before closing cover of chest.

PACKING INSTRUCTIONS CHEST # 2



FIG

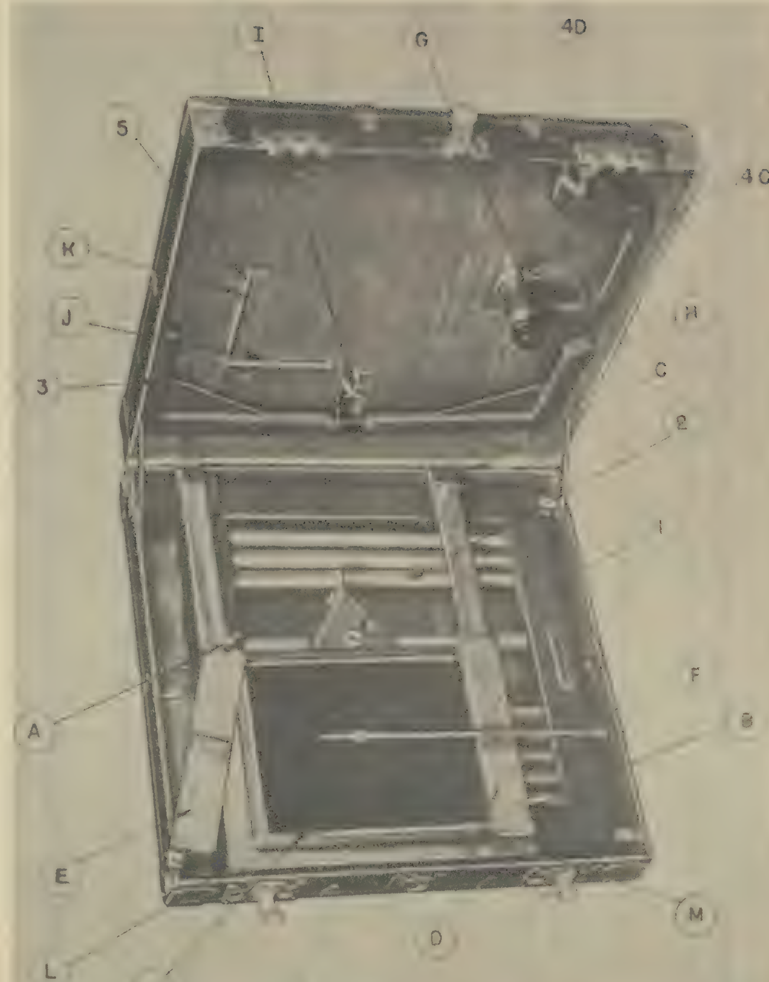


FIG. 21

(1) Two table end supports. (4A) Fluoroscopic screen arm.
(2) Three complete rails. (4B) Fluoroscopic screen.
(3) Two table leg extensions. (5) Depth scale member and marker.

PACKING INSTRUCTIONS - Place one table end support (1) into bottom of chest and place knock down rails (2) in cut-outs of support--see Figure 31. It is very important that the rails be placed in the positions shown so that the fluoroscopic screen arm and frame will clear the rails when the cover is closed.

Place second table end support over support and rail assembly in chest.

Swing framework down over assembly and tighten screws (A), (B), and (C); insert cotter pins (L) and (M).

Put black cover (not shown) over screen. Place one edge of fluoroscopic screen (4) in stationary channel (D), swing loose channel (E) in place and lock channels with long threaded rod (F).

Screw ring nut (4C) of screen arm on threaded post (G) and tighten lock screw (4D).

Press table leg extentions (3) into channels (H) on sides of chest, then place clamp (I) over ends of extensions and tighten wing nut.

Fasten depth scale member (5) with clamps (J) and (K).

TOOLS - Tools for adjustment of x-ray equipment are packed in a canvas tool bag in Field Chest #1 and consist of the following:

1 8 oz. hammer
1 6" adjustable wrench
2 screw drivers
1 combination pliers
2 sets of Allen Set Screw wrenches
1 adjustable automobile wrench
1 3/4" --10 tap
1 3/4" --die
1 1 1/4" socket wrench and handle
1 test block for foreign body localization

SECTION XXXV

GASOLINE GENERATORS

ITEM 96060
GASOLINE ELECTRIC GENERATOR
FOR USE WITH ITEM 96085

SPECIFICATION SHEET

ONAN ELECTRIC PLANTS

MODEL-OTC-38

FIELD X-RAY GENERATOR SET

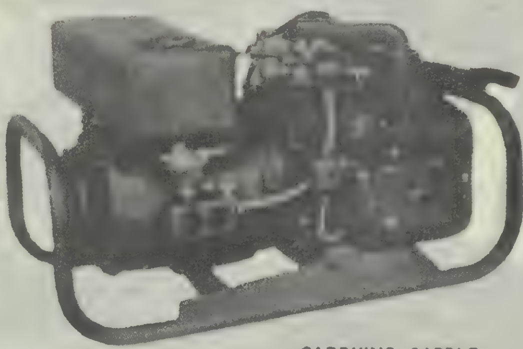
PORTABLE LIGHTWEIGHT EFFICIENT

2000 WATTS 2½ KVA

COLLAPSIBLE SOUNDPROOFED
METAL BOUND PLYWOOD CARRYING CASE

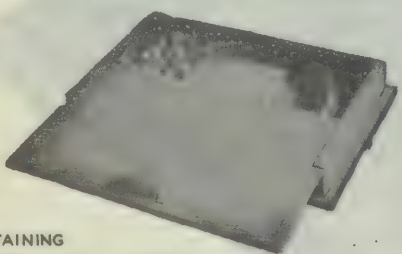
WITH
CARRYING HANDLES

COMPLETE IN ONE UNIT
MOUNTED FUEL TANK

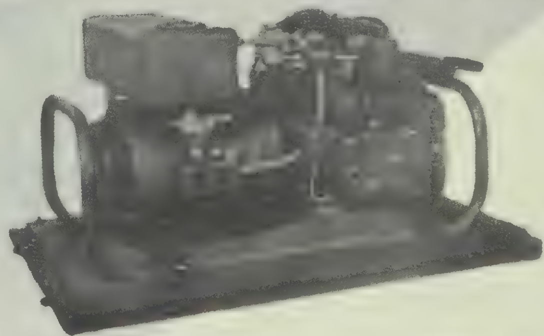


CARRYING SADDLE
ON PLANT PROPER FOR PORTABILITY

WITH ACCESSORY COMPARTMENT IN TOP PANEL

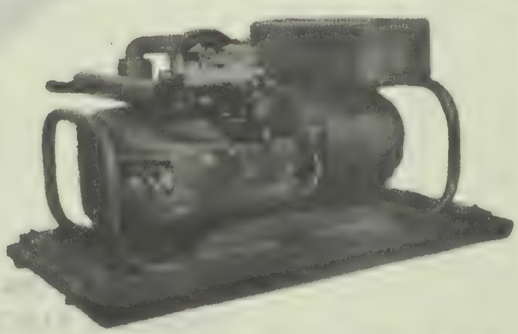


CONTAINING
NECESSARY CABLES
REPAIR TOOLS AND INSTRUCTION BOOK.



-CONVENIENTLY LOCATED TERMINAL BOX

OPERATED WITH
FRONT AND TOP OF COMPARTMENT REMOVED



PLANT RIGIDLY MOUNTED ON BASE

SPECIALLY DESIGNED NOISELESS MUFFLER

WEIGHTS - DIMENSIONS, ETC.

MODEL	PLANT LENGTH	PLANT WIDTH	PLANT HEIGHT	WEIGHT OF PLANT	CASE AND ACCESSORIES	SHIPPING WEIGHTS DOMESTIC			SHIPPING WEIGHTS EXPORT			SIZE BOXED FOR SHIPMENT		
						GROSS	NET	TARE	GROSS	NET	TARE	LENGTH	WIDTH	HEIGHT
OTC-38	30½"	18"	17½"	203#	146#	402#	349#	50#	436#	349#	84#	41"	21"	28"

41-51 Royalston Avenue **D. W. ONAN & SONS** Minneapolis, Minn.

SPECIFICATIONS & PERFORMANCE DATA
MODEL OTC-38, ONAN ELECTRIC PLANTS

ENGINE - Two Cylinder opposed, Four stroke Cycle, L-Head, Air-cooled Gasoline type.....Cast Iron Cylinder...Bore, 2-3/4"...Stroke, 2-1/4"..Piston Displacement 26.73 Cu. In....Compression Ratio, 5.9 to 1...H.P. 3.7 at 1800 RPM...4.1 at 2850 RPM.....Piston Speed, 675 Ft. per min. at 1800 RPM.....Aluminum Cylinder Head secured to Cylinders by Six Studs....Cylinder is secured to Crankcase by Five 5/16" Studs.....Cast Aluminum Crankcase with Removable Cast Aluminum Oil Sump and Mounting Base...Capacity 2-1/2 Quarts.....Aluminum Pistons with (3) Rings....Full Floating Piston Pin.....Aluminum Connecting Rod.....Cast Alloy Crankshaft Timing Gear.....Replaceable Valve Seat Inserts and Valve Guides.....Both the Intake and Exhaust Valves are #2112 SAE Steel.......Tappets are Light weight Tubular type with Conventional Adjustment.

Bearings - Front and Rear Crankshaft Hi-Lead Bronze. Front Camshaft, Bronze, Sleeve...Rear Camshaft, Babbitt-Lined Steel-Backed.

LUBRICATION - Full Pressure and Splash.......Oil is forced by a Positive Displacement Piston type Pump located in the bottom of the Oil Sump, and driven by an Eccentric on the Camshaft.....Oil is forced to both Crankshaft Main Bearings where it is led through the drilled passages in the Crankshaft to the Connecting Rod Bearings where it is led through the drilled passages in the Crankshaft to the Connecting Rod Bearings......An Adjustable By-pass on the Oil Pump maintains a constant pressure of approximately 25 pounds per square inch....Oil is sprayed from the Crank Pin and Main Bearings to lubricate all other Internal parts of the Engine..... Crankcase ventilated---fumes led through Intake System.

COOLING - Cooling of Cylinders and other Heat Radiating parts of the engine, is accomplished by a Centrifugal type Blower mounted at Front of Engine, drawing Air through a Grilled opening at the center of a stamped Housing, and discharging outward at High Velocity over each of the Cylinders, Cylinder Heads, Valve Ports and Guides...Even distribution and careful directing of the Air Stream has resulted in a low average Temperature throughout the Engine...Air is discharged upward from a Cylinder, where it may be collected by a suitable shrouding, to be directed to free air in the event the Plant is operated in a closed Housing.....To prevent "cooking" after the Engine is shut down, a natural thermal flow of Air is maintained, due to the location of the Cylinders above the Air Inlet opening of the Blower Housing.

IGNITION - Ignition is supplied by a Flywheel type Magneto of unique construction with extremely High Output at low Cranking Speed, (5000 Volts at 150 RPM) and (8000 Volts at 1800 RPM) running speed.....Two Ignition Coils are mounted on a Stationary Laminated Steel core within the Flywheel....The Primary Circuit of each Coil is connected to an External Interrupter (breaker mechanism), mounted on top of Crankcase.......The Mechanism is dustproof, Moisture-proof and Radio Shielded..... A non-metallic Plunger operated by a Cam on the Engine Camshaft, opens the Ignition Breaker Points at each Camshaft revolution, whereupon a Spark is delivered to each Cylinder from the individual coil.....A distributor is eliminated......Two Almico Magnet Inserts in the Flywheel provide the energy to the Magneto.....High-Tension Spark Plug Cables are encased in Flexible Metallic Braid which is grounded inside the Magneto Housing and at the metallic Spark Plug Cover..The Spark Plugs are 14 mm. Automotive type, located over the Intake Valve in each Cylinder Head, and are mechanically and electrically shielded by a Cast Aluminum Cover which is clamped over both the Spark Plug Base and High-Tension Cable Shielding...A Flexible Lead is brought out from Primary Coil Circuit of Magneto to a Push Button conveniently located in Air Housing....Pressing the Push Button grounds Magneto and stops the Plant.

CARBURETOR - The Carburetor used on the OTC is the down draft type Zenith, Model TU3YI, 16 mm. venturi.....Unit has set Main Jet with Idle Jet locked in place at the factory.....Carburetor will perform normally at any degree of inclination up to 30 degrees from vertical in any direction.....Manual Choking is employed.

AIR CLEANER - A dry type Intake Air Filter is an Integral part of the Carburetor as standard equipment.....This Air Cleaner is designed to allow operation of the Engine at normal speed without intake of water when it is sprayed at the Intake Opening from a 1/2" hose....An Oil Bath type Air Filter can be supplied if the Plant is operated continuously under Extremely Dusty Conditions.

GENERATOR - The Generator is Four-pole operating at 1800 RPM, 60 Cycle, A.C.....The Generator Frame is Carried directly on the Engine Crankcase by an Aluminum Adapter Casting with Slotted Openings, through which Cooling Air is discharged by a Centrifugal Blower Fan on the Generator Armature Shaft...This Casting also forms the rear section of Crankcase and carries Rear Main Bearing...The Generator Armature Shaft is inserted in a female taper in the rear of the Engine Crankshaft.....A Drawbolt through the Armature Shaft, with Hexagon Nut at rear, joins the Armature and Crankshaft into an Integral Unit.....This allows driving and supporting of the forward end of the Armature.....The outboard end of the Armature is run in a Grease-sealed type Ball Bearing.....A Cranking Shieve is provided on the Armature Shaft beyond the Generator Housing....Generator Frame is a rolled Steel Ring piloted in the Engine Generator Adapter and carrying the Rear Generator Support Casting.... Four Bolts pass through the Generator Frame and into the forward adapter....Removal of Four Nuts from these studs and loosening of the Armature Through-bolt Nut, allows the removal of the Generator from the Engine.

All Commutators are Hard Drawn Copper, set in Mica...All Collector Rings are Cast Bronze, Mica Insulated.....Brushes are mounted in the Rear Generator Support Casting and are carried in Drawn Brass Guides.....The Rear Generator Support Casting is covered on both sides and tip by a sheet Cover, the bottom being left open for Cooling Air Intake.....The Generator is Drip-proof.....All Steel Laminations used are of the Highest Grade obtainable.....All Winding Wire is of the Best Type suitable for the purpose.....All Armature and Field Coils are twice Impregnated in Insulating Varnish and Baked to insure against even severe Tropical conditions causing Electrical Breakdown.

CONTROL SYSTEM - The Engine is Manually Started using a Cable or Rope for Cranking.....The Plant must be started Manually whenever Service is required, but it can be stopped from a Remotely located Stop Button Connected to the Primary Circuit of the Magneto.

FUEL SYSTEM - A Mechanical Diaphragm Automotive type Fuel Pump is an integral part of the Engine, and pumps Fuel from the Fuel Tank atop the Generator (can be located not more than 12 feet below the pump level) to the Carburetor...... The Pump incorporates a screen and a glass bowl Filter Chamber to eliminate foreign material from the bowl.

SATISFACTORY OPERATING FUELS - The OTC Engine can be satisfactorily operated on all fuels from 67 to 100 octane, leaded or non-leaded types......Modifications in Compression Ratio and Ignition Timing are made to customer's specifications of Fuel......Increased Horsepower Output to the extent of 25% above rated horsepower can be obtained by using higher octane fuels (above 98).

INSTALLATION - The location of this plant is important as this model is a portable type, and will be frequently operated on the ground. A place should be selected where it will be free from sand, mud and dust, if possible. Although the unit is protected against normal exposure, it is desirable to shelter it as much as possible.

A plant in portable service must be handled extensively. When it is moved about, great care should be taken by the operator to see that it is not damaged. If the plant is filled with gas and oil, it should be kept in an upright position.

EXHAUST - When this plant is operated in a closed or even well ventilated room, the exhaust pipe must be connected to dispose of the carbon-monoxide gas, which otherwise, would cause illness or even death to personnel.

It is also important when operating in a closed vehicle that some means of disposing of the exhaust gases of the engine is provided. A flexible metal hose must be connected in this case to the exhaust muffler outlet pipe, and run outside the vehicle. This pipe must be securely connected to the plant, and shall be of a type that is reasonably gas-tight to prevent leakage.

SETTING-UP PLANT FOR OPERATION - Sufficient and proper ventilation of fresh air must be provided, if the plant is installed in a closed room or operated in a closed vehicle.

In setting-up the plant, the generating set will be enclosed in a carrying case, and the first step in setting-up for operation will be to select a location as previously described.

When the plant has been properly located, the harness fasteners can be removed from the trunk clasp, and the trunk clasp then opened to remove the top lid. The top lid can be removed and laid down in an inverted position, so that a sliding panel may be removed to gain access to the cable, ground rod, and tool kit. The wide door adjacent to the line terminal box must then be removed by opening the trunk clasp and sliding this member upward, and the channel section provided for this purpose.

When this has been done, the plant is ready for visual inspection, such as checking quantity of fuel, oil level, and any general damage that may have occurred to the unit during transportation.

The gasoline selected should be of the regular or clear type, and preferably not the highly leaded Tetraethyl fuel. The gasoline should be of the proper gravity that suits the particular weather and temperature conditions.

The fuel tank on the plant has a capacity of two gallons and is filled by unscrewing the cap and filling with a suitable measure or funnel that will prevent spillage of the gasoline.

Before attempting to start the plant, it is necessary to open the vent cap on the tank to relieve any vacuum that might be formed.

OILING - After the plant has been properly installed, the crankcase should be filled with 2½ quarts of SAE-20 oil, if the engine is operating at a temperature above 50° F., and SAE-10 oil if the engine is operating at a temperature below 50° F.

The oil level is indicated by the bayonet gauge on the oil filler cap. The oil level should be maintained between the full and the low mark and never allowed to drop to the DANGER mark. The oil level should be checked daily, until the operator is familiar with the natural oil consumption of the engine.

Change oil frequently. The oil must be drained at least once each 100 to 200 hours of operation, depending on the nature of the service the plant is subjected to. In low temperatures change the oil more frequently. In average operating temperatures, between 50° to 80° F., the oil may be changed each 200 hours of operation. If the plant is operated in temperatures above 80°, it should be changed after each 100 hours of operation.

Cold weather operation. If starting becomes difficult, it is satisfactory to use an SAE No. 10-W winter oil, or dilute SAE-10 oil with not more than 10% good clean kerosene. The oil should be changed more frequently than 100 hours if this practice is used. (See Cold Winter Operation Sheet in front of manual).

STARTING THE ENGINE - Before attempting to start the plant, be sure that the fuel-shut-off valve under the fuel tank is open. Also see that the air vent in the fuel tank cap is open.

The electric plant must be properly grounded with the grounding rod furnished with the unit to the ground terminal on top of the live outlet box on plant.

Be sure that the main line switch is open before starting the plant.

Starting the engine is accomplished by winding the starting rope around the grooved pulley on the generator end of the unit, giving a quick pull.

When the engine starts, it will be necessary to continue to provide a richer than normal mixture until it is warmed up. During the first few minutes of warm-up, the choke button should be pushed gradually inward until the full open position is reached without the engine hunting or sputtering from a lean mixture.

CONNECTING LOAD TO X-RAY UNIT - Be sure operation of the x-ray unit is thoroughly understood before attempting to operate.

Before the main line switch to the x-ray unit is closed, the power unit should be run for a slight warm-up period, long enough so that its operation is stable and no further choking is necessary.

After the x-ray unit has been turned on and if at this time there is any unsteadiness of operating or hunting of the governor, the engine is too cold and requires a few minutes of additional warm-up.

Operation of the generating set may be continued for intermittent or extended periods. Should the occasion arise for continuous operation, it will be necessary to check the fuel level at regular intervals of approximately two hours, and the oil level at intervals of 15 to 20 hours.

STOPPING THE PLANT - At the conclusion of the operating period, the machine is stopped by pressing the ignition stop button located on the blower air housing of the machine. This button cuts off the ignition and immediately stops the engine.

When the engine is to be shut down for the last time at some particular locality, it is desirable to stop the engine by shutting off the fuel valve on the under-

side of the gasoline tank. When this is done, the engine will continue to run until nearly all the fuel is used from the carburetor. This will prevent spilling in the event the unit is tipped. When the fuel valve is shut off in this manner, it is desirable to also disconnect the x-ray units to prevent surges in voltage that will occur when the unit finally runs out of fuel. When transporting the unit, the air-vent screw shutoff on the gas tank cap should be turned all the way in. The carrying case can then be replaced over the unit and securely fastened.

ACCESSORIES AND SERVICE

FUEL PUMP - An automotive type fuel pump with the fuel filter bowl and screen is mounted on top of the engine. The filter bowl should be removed occasionally and emptied, wiped, and carefully replaced against the gasket with the lock turned up securely to insure against leakage.

CARBURETOR - Very little care or attention need be given to these carburetors, outside of an occasional cleaning perhaps once a year, to insure that the bowl has not become filled with sediment. Irregular operation of the engine, hard starting, or loss of power, may indicate that the main or compensating jets of the carburetor have been clogged. It is then necessary to remove the float bowl cover of the carburetor to remove and clean the main jet.

SPARK PLUGS - The spark plugs used on this plant are 14 mm. Champion No. J10. To insure proper results, the spark plugs should be removed and cleaned once a month. The spark plug cap should be set at .025". Spark plugs should be replaced after 150 to 200 hours of operation.

BREAKER POINTS - Breaker points should be inspected occasionally, cleaned and set at .020" clearance. If the points have become badly burned or pitted, they should be replaced. An inspection should be made of the breaker arm return spring to see that it is in its proper position.

Rapid deterioration of the breaker points can be caused by a defective condenser or excessive oil. The breaker point condenser is mounted directly behind the breaker arm on the breaker mechanism housing. If excess arcing occurs at this point, a faulty condenser is indicated and should be replaced by a standard Auto-Lite or replacement condenser of .25 mfd. capacity.

MINOR LUBRICATION - Once a month, place a light lubricating oil on the following parts:

Throttle shaft bearings of carburetor.
Governor ball joint.
Carburetor choke shaft bearing.

After six months of operation, remove the air filter from the engine, clean thoroughly in gasoline, dip in used lubricating oil, allow to drain at least two hours, and replace on the carburetor.

Also remove the brush cover from the generator, and inspect all brushes. Replace those that are worn.

The generator ball bearings should be cleaned and refilled with ball bearing grease. Use about 1 tbsp. to refill the bearing. Replace the gasket and tighten the gasket plate carefully.

Once each year or after each 2,500 or 3,000 hours of operation, the engine should be given a thorough going over, including inspection of pistons, piston

rings, valves, crankcase, etc. Before attempting to grind valves or replace piston rings, refer to service manual and to OTC valve and cylinder service sheet. It is advisable when grinding valves to replace the piston rings.

When reassembling the plant, use new gaskets always. Before reassembling the plant, inspect the valve guides for wear or carbon deposits which will decrease the valve stem clearance caused by sticking of the valves.

The valve stems sticking in the guide are more often the cause of trouble than any other source, and serious damage to the plant can result from overheating due to this source alone.

TAPPET ADJUSTMENT - The tappets should be adjusted after the cylinders have been reassembled and the cylinders tightened securely to the crankcase. The proper clearance between the valve stems and the valve tappet screw heads, should be .008" to .010" on both the intake and the exhaust valve. The tappet adjustment must be made on each cylinder with the piston at top dead center on the compression stroke.

Check this clearance after the engine has been started and run for a short time. It is advisable to go over each of the cylinder head bolts to be absolutely sure they are dead tight after the engine has run for a short time.

GOVERNOR OPERATION - The proper operation of the governor assemblv is absolutely essential as it controls the speed of the engine and the voltage output of the generator. When the governor and governor booster are operating normally, the speed of the engine will be constantly controlled at approximately 1,800 RPM. The governor adjustment is in a locked position and further adjustment should not be attempted.

If the governor is dissembled or if the carburetor is removed from the engine, resetting of the external parts of the governor will be necessary. This is done in the following manner;

Readjusting. The governor spring forces the throttle shaft to the full open or full speed position. Be sure the throttle butterfly is in the proper position by loosening the clamp screw and holding the throttle arm on its shaft. Turn the throttle shaft with the fingers clockwise, looking downwards, and allow the governor spring to return the governor arm to its normal open position. Now lock the arm securely on the throttle shaft.

If the governor arm has come loose from the governor shaft which extends from the front gearcase, the clamp holding the arm to the shaft should be loosened, and with a screwdriver inserted in the slot in the top of the governor shaft turn the shaft clockwise (to the right looking downward) as far as possible and hold it in that position. While the governor spring holds the arm in its normal idle position, relock the clamp screw securely. These operations will restore the governor to its original setting and it should function properly. There is no routine servicing which must be taken care of on this governor assembly, other than placing a drop of oil occasionally on the link between the throttle arm of the carburetor and the governor arm, and on the throttle shaft and the carburetor. None of the parts of the governor should require replacement during the life of the plant.

REMOVAL OF CARBURETOR WITHOUT UPSETTING GOVERNOR OR GOVERNOR BOOSTER SETTING - This can be accomplished by the following procedure: First, remove the cotter pin on the carburetor side of the throttle lever which goes through the connecting link between the throttle lever and the governor arm. Next, remove both fuel line and the sediment bowl from the fuel pump. Then remove the six screws holding down the intake manifold. The complete assembly can now be removed from

the engine with little trouble.

MOST COMMON CAUSE OF TROUBLE - Most troubles can generally be traced to the following conditions:

Use of too heavy oil in the engine.
Oil not changed at specified periods.
Use of inferior or colored fuel.
Dirt, water or ice in fuel system.
Engine overheated.
Poor ventilation.
Moisture, dirt or dusty conditions.
Dirty ignition breaker points or incorrect spacing.
Fouled spark plugs.
Excessive carbon in combustion chamber.
Poor installation of plant.
Defective wiring, or plant overloaded.
Lack of proper care.

If these conditions are carefully watched for, very little trouble should be encountered and the performance of the plant should be very satisfactory.

BRIEF OPERATING & MAINTENANCE INSTRUCTIONS:

1. Keep plant free from dirt or excessive moisture as much as possible.

2. Be sure operation of the x-ray unit is thoroughly understood before attempting to operate.

3. Whenever operating x-ray unit from this portable power plant, line adjuster strap must be set at 128 volts (highest voltage setting).

4. Electric plant must be properly grounded with the grounding rod furnished with the unit, to the ground terminal on top of the line outlet box of plant.

5. Sufficient and proper ventilation of fresh air must be provided if plant is installed in a closed room. Provisions should also be made to carry any exhaust gases (poisonous - resulting in severe sickness and very often death) from the room in which plant is operating.

6. Check quantity of fuel and oil. Use only grades recommended by the manufacturer. (See Service Manual)

7. Be sure fuel shut-off valve under fuel tank is open.

8. See that air vent in fuel tank cap is open.

9. Also that main line switch is open (off) before starting the plant.

10. This machine employs "manual" choking, and should be choked to suit temperature conditions. A warm-up period, until engine runs smoothly without further choking, or until the kilovolt meter reading does not vary over three kilovolts, should be allowed before attempting to take pictures with the x-ray unit.

11. There must be not more than a ten kilovolt drop from "no load" to "operating load", as operating with a greater drop may cause damage to the x-ray equipment.

12. The main carburetor jet on this unit is a "set jet". Correct operating adjustment is set at the factory and should not be changed. Only service required is occasional cleaning.

COMPLETE DISASSEMBLY OF THE OTC-17 PLANT:

Shut off the gas below the tank.
Disconnect the gas line between the tank and fuel pump.
Remove the gas tank.
Remove the rope sheave.
Remove the grease retainer washer and grease retainer gasket.
Remove the generator bell housing band.
Raise the brushes.
Remove the 4 generator through stud nuts.
Remove the generator frame and generator and bell.
Loosen the nut from the armature through stud and hit the stud a sharp blow with a lead hammer.
Remove the armature through stud nut.
Remove the armature. The generator blower is bolted to the armature.
Remove the muffler.
Remove the engine blower housing.
Remove the spark plug shields.
Remove the spark plugs.
Remove the cylinder air housings.
Remove the air cleaner and air cleaner adapter casting.
Remove the crankcase breather tube.
Remove the governor spring bracket.
Remove the fuel pump with the fuel pump adapter casting.
Remove the linkage between the governor arm and carburetor.
Remove the intake manifold and carburetor.
Remove the breaker box cover.
Disconnect the primary ignition wire from the breaker box.
Remove the breaker box.
Remove the breaker plunger.
Remove the cylinder heads.
Remove the valve box cover.
Remove the cylinders.
Remove the valves from the valve guides.
Remove the valve tappet or valve lifter.
Loosen the screw holding the flywheel to the crank and tap the head of the screw with a hammer, thereby loosening it from the crank.
Remove the cap screw and the blower.
Remove the Woodruff key in the crank.
Remove the gear case cover (Note: The governor arm has not been and should not be loosened from the paddle shaft.)
Remove the crank nut.
Remove the crankshaft timing gear.
Remove the crankcase from the oil base.
Disconnect the oil lines and remove the oil pump.
Remove the camshaft.
Remove the generator adapter casting.
Remove the crankshaft.

ORDERING PARTS FOR GASOLINE GENERATOR - If the following instructions are followed when ordering parts, it will greatly speed up the handling of orders and aid in prompt service.

When ordering parts, BE SURE to specify part for ONAN Plant MODEL NO.______ SERIAL NO.____________________.

The Model and Serial Number of the ONAN PLANT will be found on the name plate located on the side of the engine crankcase.

Parts MUST also be ordered by PARTS NUMBER and by DESCRIPTION IN FULL AS given in Parts List. DO NOT ORDER PARTS IN SETS. Always give exactly the quantity of each part desired.

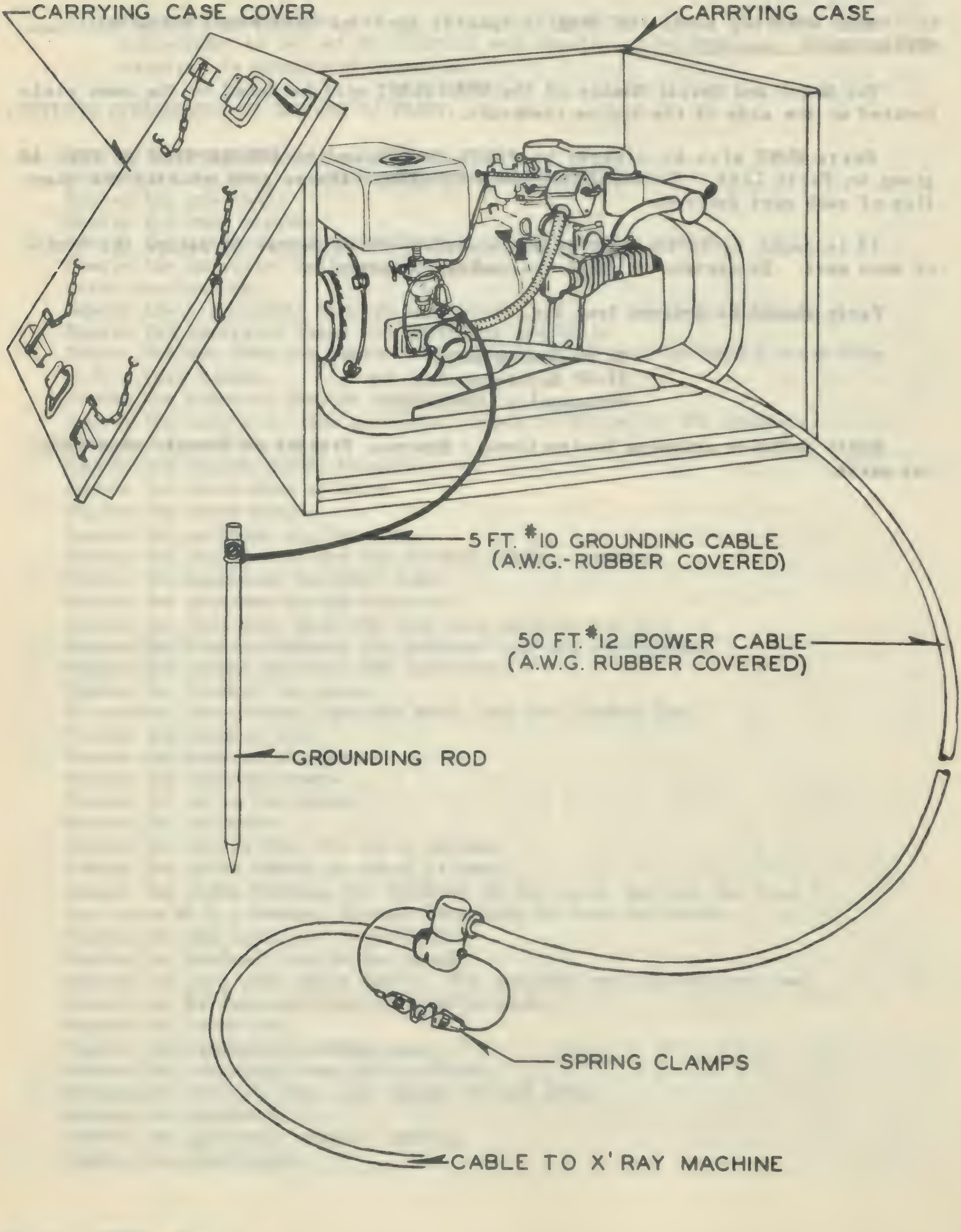
If in doubt as to the part or parts needed, it is better to return the broken or worn part. Be certain to label the package properly.

Parts should be ordered from the,

D. W. Onan & Sons
37-57 Royalston Ave. No.
Minneapolis, Minnesota

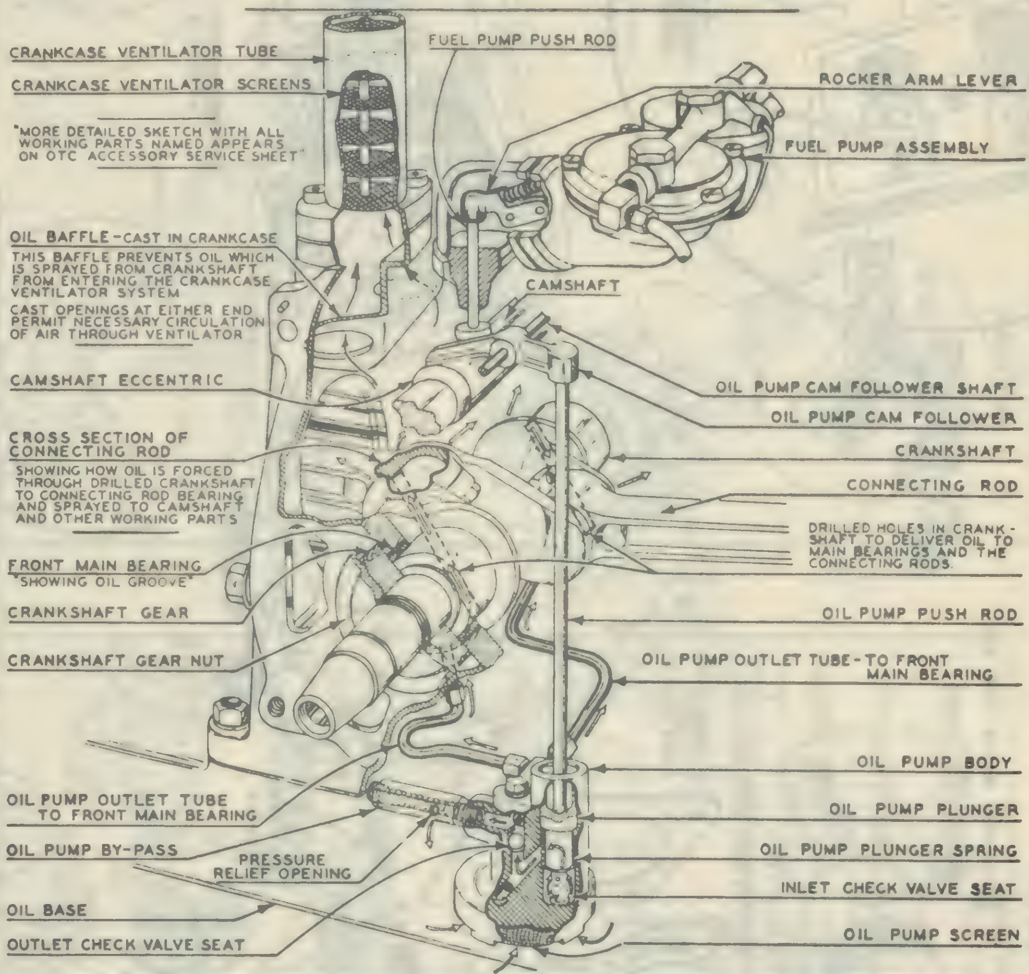
State definite shipping instructions - Express, Freight or Parcel, when ordering parts.

METHOD OF CONNECTING X RAY MACHINE TO PLANT



OIL AND FUEL PUMP ASSEMBLY
MODEL – O.T.C.

A CLOSE STUDY OF THE ACCOMPANYING SKETCH WILL ENABLE THE OPERATOR TO BECOME THOROUGHLY ACQUAINTED WITH THE OPERATING PRINCIPLE OF THE FUEL AND OIL SYSTEMS OF THE MODEL "O.T.C." ENGINE. PARTS ARE SHOWN IN EXACT RELATION TO THEIR POSITION IN THE ENGINE. OPEN ARROWS IN SKETCH INDICATE DIRECTION OF FLOW OF OIL, THROUGH PUMP TO CRANKSHAFT AND CONNECTING ROD BEARINGS AND BY SPRAY TO OTHER MOVING PARTS.



THE FUEL PUMP OF THE MODEL "O.T.C." ENGINE IS OPERATED BY THE FUEL PUMP PUSH ROD WHICH RIDES ON AN ECCENTRIC OF THE CAMSHAFT. THE PUSH ROD IN TURN OPERATES THE FUEL PUMP ROCKER ARM LEVER PUMPING FUEL INTO THE FUEL FILTER BOWL AND ON THROUGH INTO THE CARBURETOR.

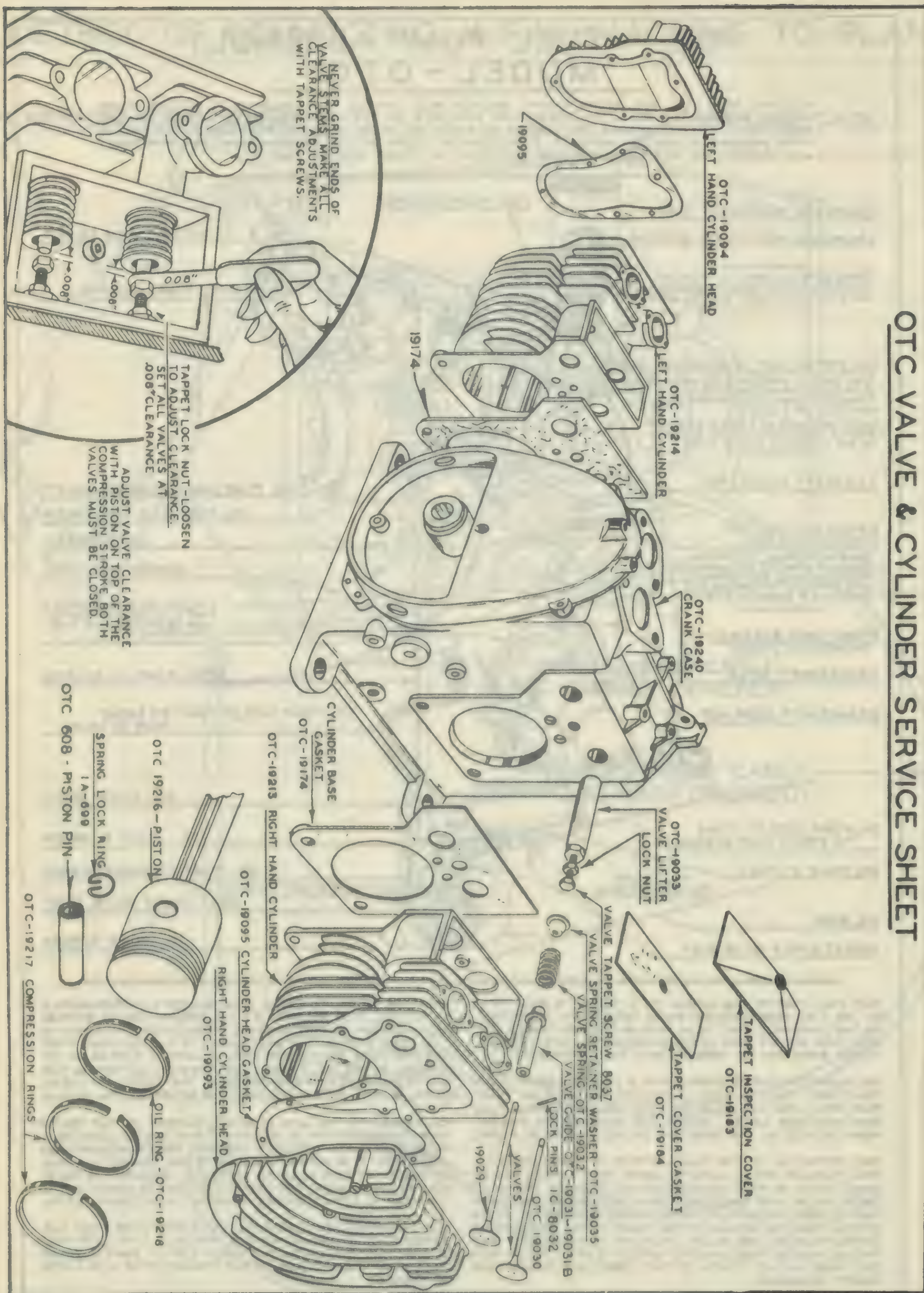
THE OILING SYSTEM IS OPERATED BY A CAM FOLLOWER LEVER WHICH RIDES ON THE SAME ECCENTRIC AS THE FUEL PUMP PUSH ROD. THE OIL PUMP PUSH ROD OPERATING FROM THIS CAM FOLLOWER LEVER, WORKS THE PLUNGER OF THE OIL PUMP LOCATED IN THE BASE OR OIL RESERVOIR OF PLANT.

THE OPERATION OF THE PUMP PROPER IS AS FOLLOWS: THE PLUNGER SPRING LOCATED UNDER THE PLUNGER FORCES SAME TO ITS UP POSITION SUCKING OIL THROUGH THE INLET CHECK VALVE INTO THE PUMP. THIS SUCTION AT THE SAME TIME CLOSES THE OUTLET CHECK VALVE KEEPING OIL IN THE SYSTEM FROM RETURNING TO THE PUMP. ON THE DOWN STROKE OF THE PLUNGER, THE INLET CHECK VALVE IS CLOSED AND THE OIL FORCED THROUGH THE OUTLET CHECK VALVE INTO THE PUMP OUTLET TUBES TO THE FRONT AND REAR CRANKSHAFT BEARINGS.

WHEN THE PRESSURE IN THE PUMP EXCEEDS APPROXIMATELY 50 POUNDS, IT IS RELIEVED BY THE SPRING LOADED BY-PASS VALVE SHOWN IN SKETCH ABOVE. THIS EXCESS PRESSURE IN THE PUMP FORCES THE BALL CHECK IN THE BY-PASS PAST THE PRESSURE RELIEF OPENING, ALLOWING EXCESS OIL TO RETURN TO THE OIL BASE. ANY FOREIGN MATTER IN THE OIL IS PREVENTED FROM ENTERING THE SYSTEM BY THE OIL PUMP SCREEN WHICH ENCLOSES THE ENTIRE BOTTOM OF PUMP.

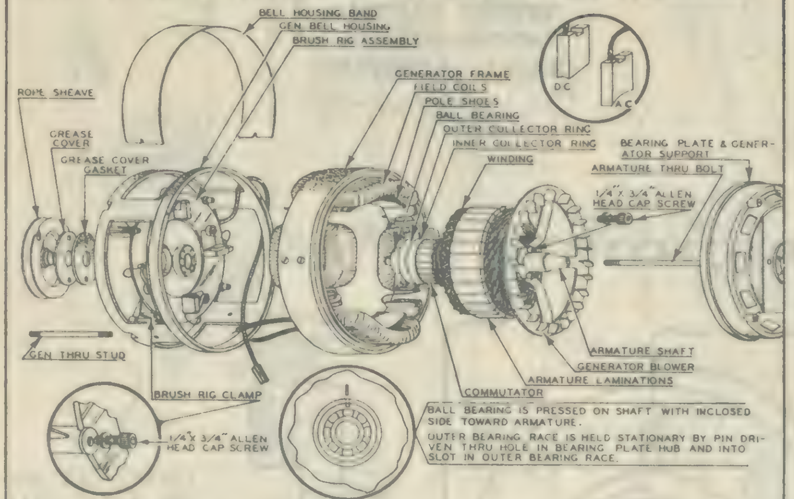
OIL FORCED TO THE MAIN BEARINGS ENTERS AT THE CENTER OR GROOVED SECTION OF BEARINGS. THIS GROOVE COINCIDES WITH THE DRILLED OPENINGS THROUGH THE CRANKSHAFT AND ALLOWS OIL TO BE FORCED THROUGH TO THE CONNECTING ROD BEARINGS. AT THIS POINT OIL IS FORCED THROUGH THE CREVICES AT THE SIDES OF THE CONNECTING ROD BEARINGS AND IS SPRAYED TO THE CYLINDERS, CAMSHAFT AND OTHER PARTS.

THE CRANKCASE VENTILATOR SYSTEM IS PROTECTED FROM THE SPRAYING OIL BY AN OIL BAFFLE WHICH IS CAST INTO THE CRANKCASE. OPENINGS AT EITHER END OF BAFFLE ALLOW NECESSARY CIRCULATION OF AIR THROUGH THE VENTILATOR SYSTEM.

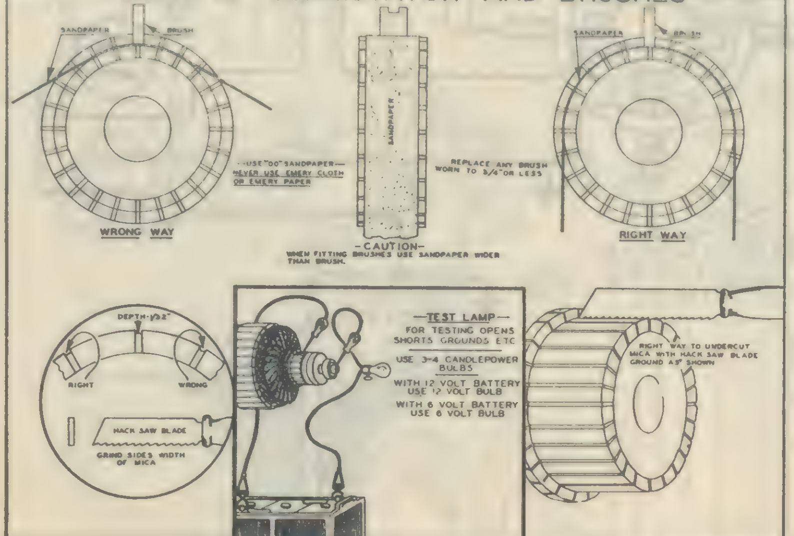


OTC VALVE & CYLINDER SERVICE SHEET
OTC-19004 LEFT HAND CYLINDER HEAD
19095
OTC-19214 LEFT HAND CYLINDER
19174
OTC-19240 CRANK CASE
OTC-19033 VALVE LIFTER
LOCK NUT
TAPPET INSPECTION COVER
OTC-19183
TAPPET COVER GASKET
OTC-19184
VALVE TAPPET SCREW 8037
VALVE SPRING RETAINER WASHER-OTC-19035
VALVE SPRING-OTC-19032
VALVE GUIDE OTC-19031-19031B
LOCK PINS 1C-8032
OTC 19030
VALVES
19029
CYLINDER BASE GASKET
OTC-19174
OTC-19213 RIGHT HAND CYLINDER
OTC-19095 CYLINDER HEAD GASKET
RIGHT HAND CYLINDER HEAD
OTC-19093
OTC 19216—PISTON
SPRING LOCK RING
1A-699
OTC 608 - PISTON PIN
OIL RING - OTC-19218
OTC-19217 COMPRESSION RINGS
NEVER GRIND ENDS OF VALVE STEMS MAKE ALL CLEARANCE ADJUSTMENTS WITH TAPPET SCREWS.
.008"
.008"
.008"
TAPPET LOCK NUT-LOOSEN TO ADJUST CLEARANCE. SET ALL VALVES AT .008"CLEARANCE
ADJUST VALVE CLEARANCE WITH PISTON ON TOP OF THE COMPRESSION STROKE. BOTH VALVES MUST BE CLOSED.

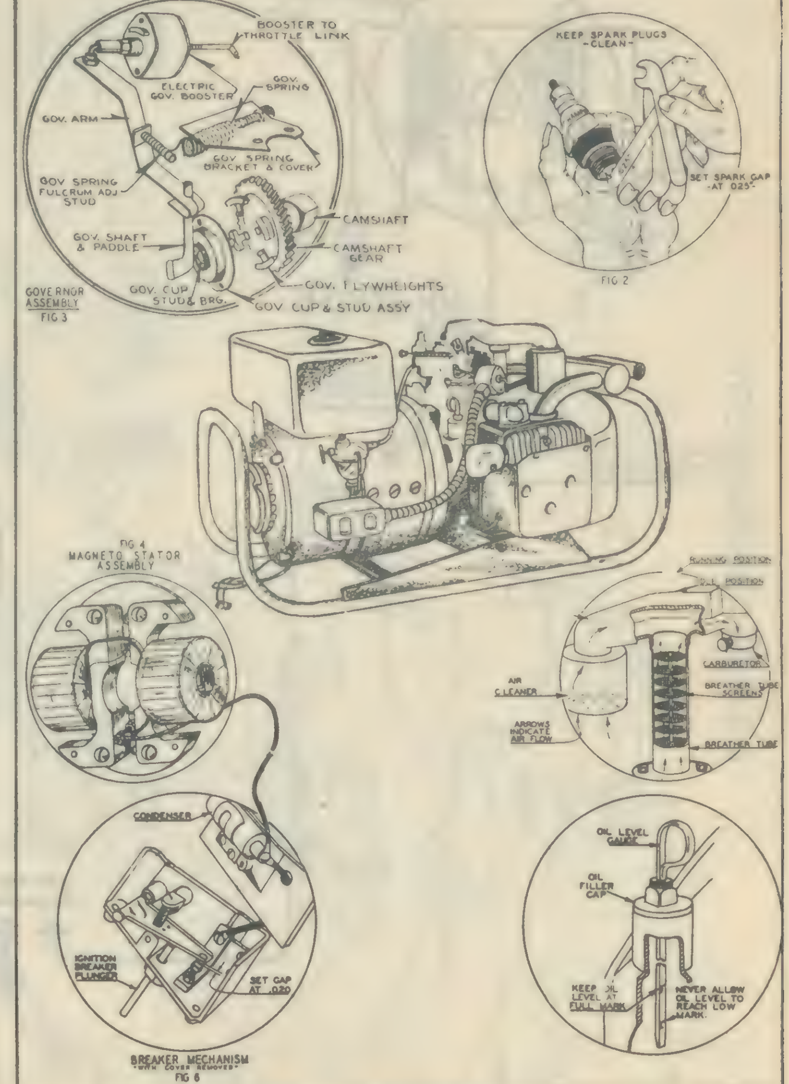
OTC ALTERNATING CURRENT GENERATOR ASSEMBLY

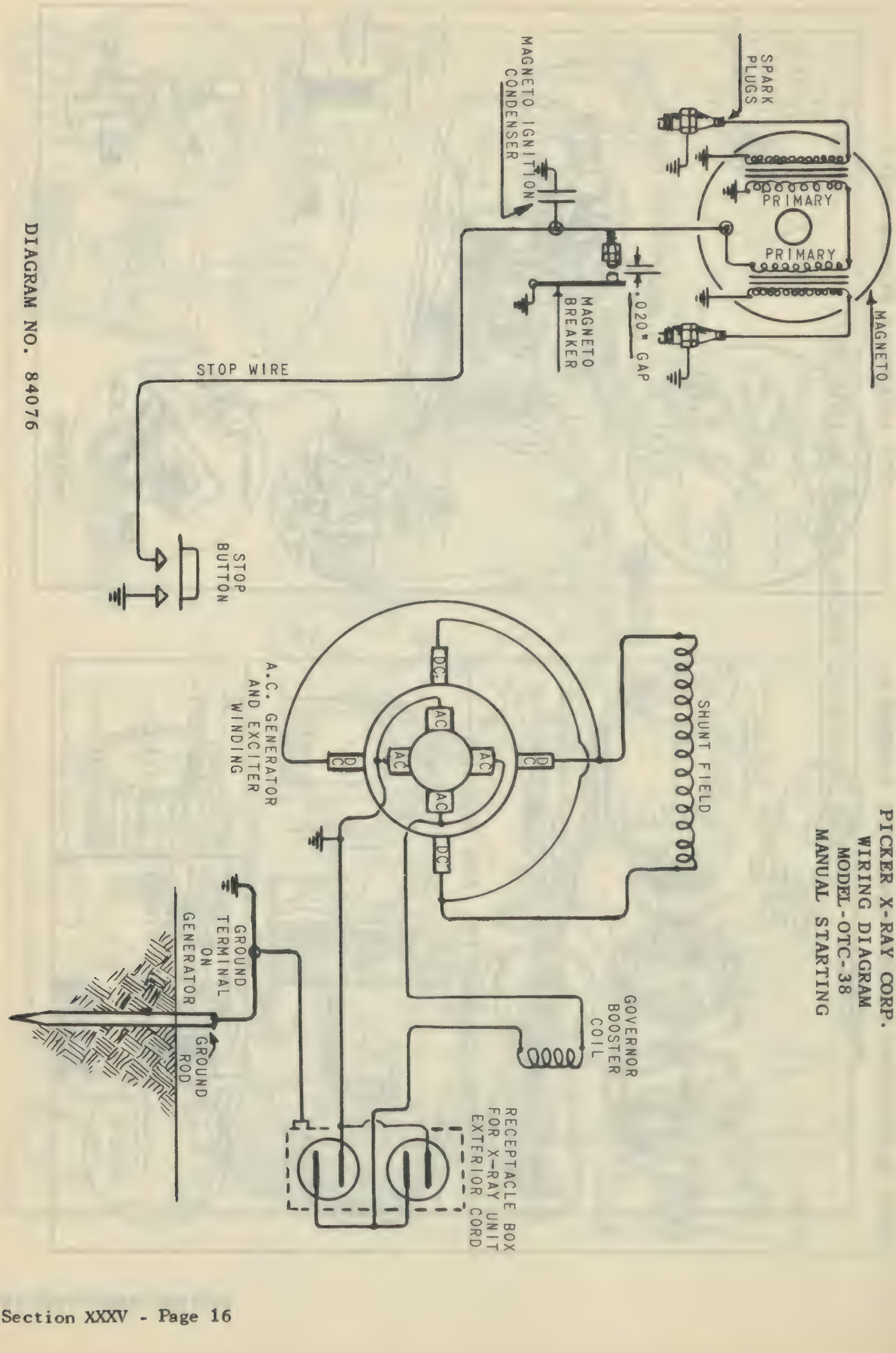


CARE OF COMMUTATOR AND BRUSHES

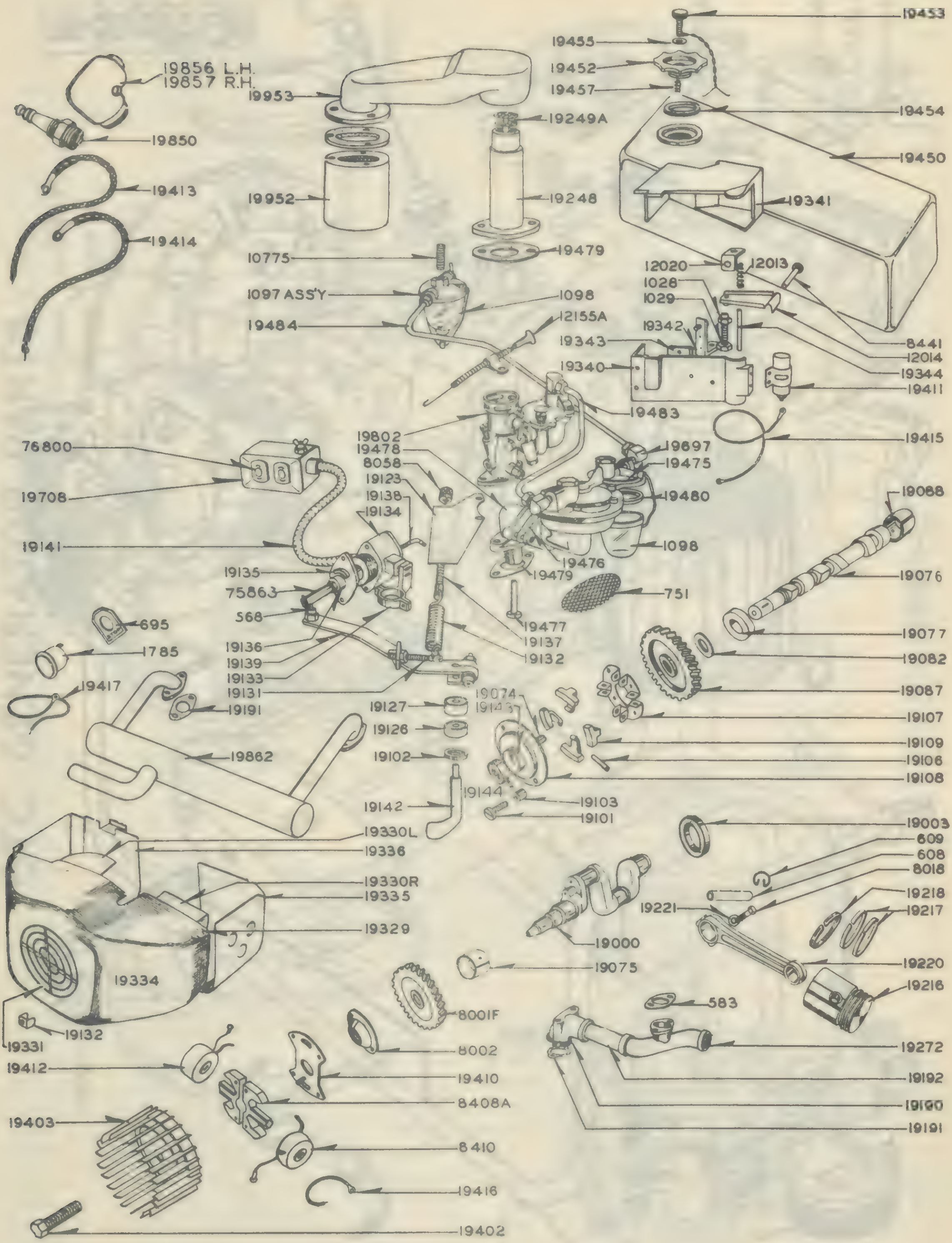


OTC ACCESSORY SERVICE SHEET

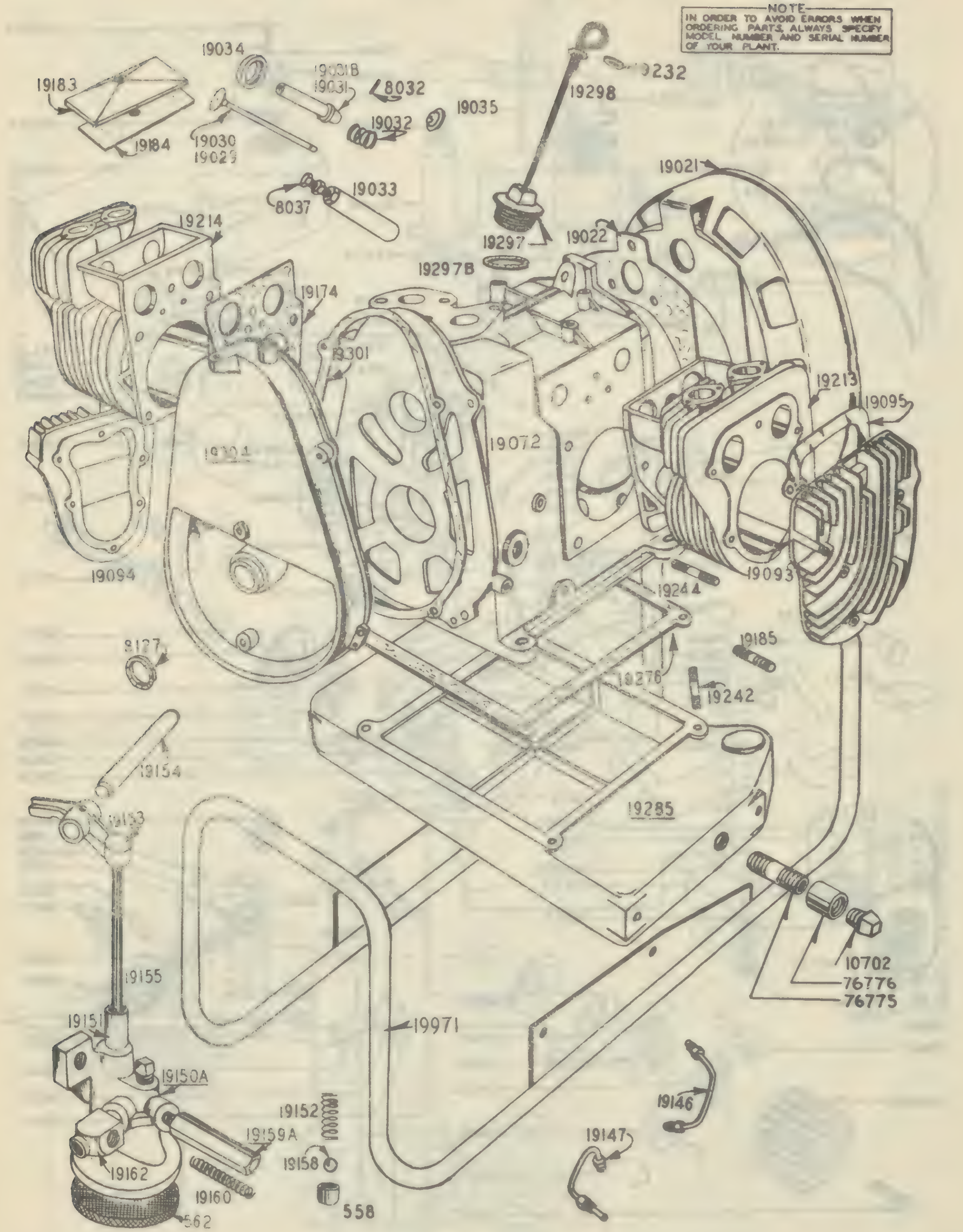



PICKER X-RAY CORP.
WIRING DIAGRAM
MODEL-OTC-38
MANUAL STARTING
SPARK PLUGS
MAGNETO IGNITION CONDENSER
PRIMARY
PRIMARY
MAGNETO
.020" GAP
MAGNETO BREAKER
STOP WIRE
STOP BUTTON
SHUNT FIELD
DC
AC
A.C. GENERATOR AND EXCITER WINDING
GOVERNOR BOOSTER COIL
GROUND TERMINAL ON GENERATOR
GROUND ROD
RECEPTACLE BOX FOR X-RAY UNIT EXTERIOR CORD
DIAGRAM NO. 84076

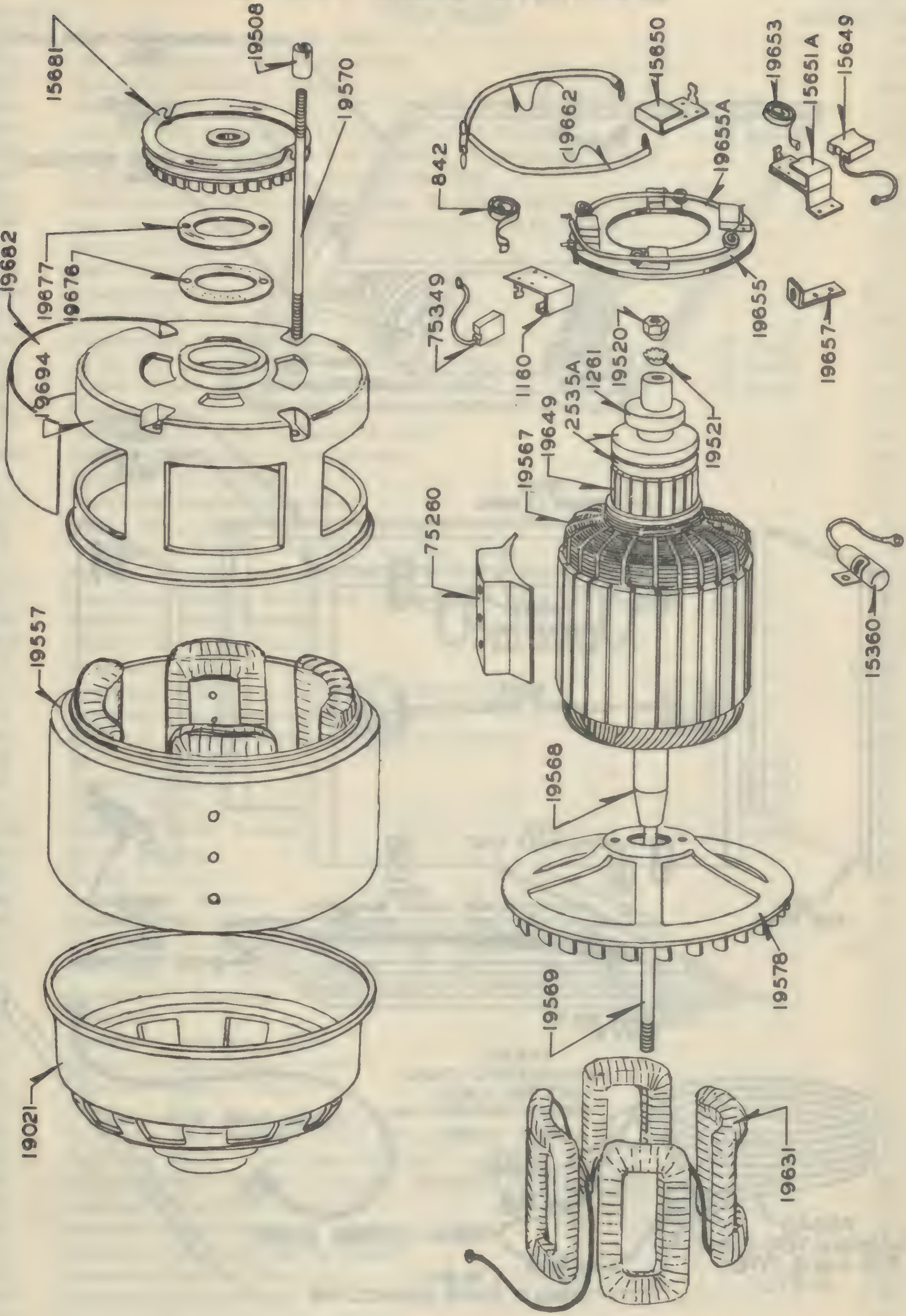
OTC ENGINE PARTS



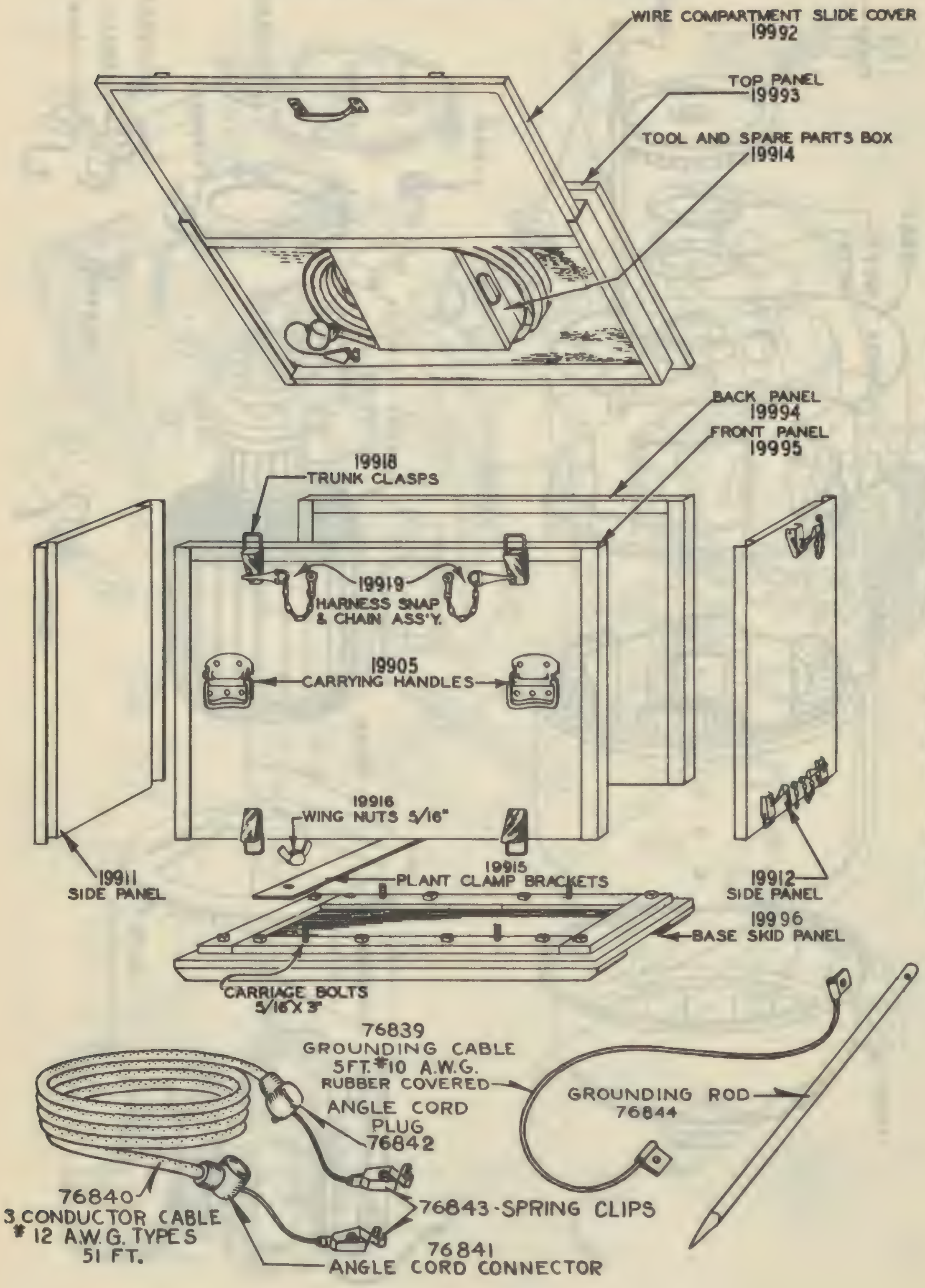
OTC ENGINE PARTS



OTC GENERATOR PARTS



CARRYING CASE PARTS



OTC ENGINE PARTS LIST

PART NO.	PART NAME	APPROXIMATE VALUE, EACH
558	Check Valve Seat - Oil Pump. . . . . $	.75
562	Oil Pump Screen #24 Mesh Brass	.50
568	Governor Arm Ball Joint.	.20
608	Piston Pin - 3/4" x 2 1/4"	.50
609	Piston Pin Lock Ring for 2 3/4" & 3" Piston. . . . . . .(4 used)	.05
750	Fuel Pump Replacement Kit (Gasket, Diaphragm, Etc.).	.75
751	A.C. Fuel Pump Filter Screen #864009	.20
1028	Stationary Contact Screw (Ign. Breaker) with Tungsten Point. . .	.35
1029	Nut for Stationary Contact Screw (Autolite #1B23).	.05
1057	Starting Rope.	.50
1098	Fuel Pump Glass Bowl	.30
8001F	Crankshaft Gear - Fibre.	3.00
8002	Crankshaft Gear Nut.	.60
8018	Connecting Rod Cap Screw (Heat Treated). . . . .(4 used)	.10
8032	Valve Spring Retainer Washer Lock Pin. . . . .(4 used)	.05
8037	Valve Tappet Screw - 1/4" x 3/4" SAE . . . .(4 used)	.25
8058	Governor Adjusting Nut	.10
8127	Gearcase Oil Seal (Graphite Cork).	.20
8408A	Magneto Coil Shoe (Laminated).	1.00
8410	Magneto Coil (Right)	2.40
8441	Ignition Breaker Arm Stud.	.20
10702	Drain Plug (oil) - 3/8" Pipe Plug.	.10
10775	1/8" Close Nipple & Filter to Fuel Tank.	.10
12013	Breaker Arm Spring	.10
12014	Ignition Breaker Arm with Pt. & Shunt Wire	.60
12020	Breaker Spring Bracket	.10
12155A	Choke Wire Assembly.	.75
19000	Crankshaft	12.00
19003	Crankshaft Oil Seal - (Victor #60562).	1.00
19021	Bearing Plate & Generator Support.	3.50
19022	Bearing Plate & Generator Support Gasket	.25
19029	Exhaust Valve. . . . .(2 used)	.75
19030	Intake Valve . . . .(2 used)	.75
19031	Intake Valve Guide . . . .(2 used)	.30
19031B	Exhaust Valve Guide. . . . .(2 used)	.30
19032	Valve Spring	.15
19033	Valve Lifter	.90
19034	Valve Seat Insert.	.50
19035	Valve Spring Retainer Washer	.10
19072	Crankcase Assembly with Bearings Fitted.	35.00
19074	Governor Cup Stud.	.20
19075	Crankshaft Bearing - Front & Rear. . . . .(2 used)	.75
19076	Camshaft	6.50
19077	Camshaft Bearing - Front	1.00
19082	Camshaft Gear Spacer Washer.	.10
19087	Camshaft Gear - Steel.	3.50
19088	Camshaft Bearing - (rear).	.65
19093	Cylinder Head - Right Hand (Alum).	3.75
19094	Cylinder Head - Left Hand (Alum)	3.75
19095	Cylinder Head Gasket - Copper Asbestos - 2-3/4" Bore	.65
19101	Governor Cup Stop Screw.	.05
19102	Governor Shaft Bearing Spacer.	.25
19103	Governor Cup Stop Screw Spacer	.05
19106	Governor Weight Pin.	.05
19107	Governor Pivot Plate	1.75
19108A	Governor Cup & Stud Assembly	.75

OTC ENGINE PARTS LIST

PART NO.	PART NAME	APPROXIMATE VALUE, EACH
19109	Governor Weight	$ .40
19126	Bearing - ND 38	1.80
19127	Bearing - ND-WC8103	1.95
19131	Governor Spring Fulcrum Adjusting Stud	.10
19132	Governor Spring	.15
19133	Governor Booster Bracket	.50
19134	Governor Booster Housing	2.00
19135	Governor Booster Housing Cover	.25
19136	Governor Booster Plunger	.25
19137	Governor Spring Adj. Stud	.15
19138	Governor Arm to Carburetor Control Rod	.40
19139	Governor Arm	.45
19141	Flexible Conduit - Booster to Outlet Box	.50
19143	Governor Bearing Cup	.35
19144	Governor Cup Bearing	.75
19146	Oil Pump to Front Bearing Tube	.65
19147	Oil Pump to Rear Bearing Tube	.75
19150A	Oil Pump Assembly	3.50
19151	Oil Pump Plunger	.75
19152	Oil Pump Plunger Spring	.10
19153	Oil Pump Cam Follower	.85
19154	Oil Pump Cam Follower Shaft	.30
19155	Oil Pump Push Rod	.25
19158	Oil Pump Check Ball - 5/16" Steel Ball	.10
19159A	Oil By-Pass Body Assembly	1.25
19160	Oil By-Pass Spring	.10
19162	Pipe Tee (Weatherhead)	.35
19174	Cylinder Base Gasket	.20
19183	Valve Box Cover - Cast. Alum	.40
19184	Valve Box Cover Gasket	.10
19185	Stud for Cylinder Head	.10
19190	Intake Adapter (For Cylinder) Cast. Alum	.85
19191	Intake Adapter Gasket	.10
19192	Intake Adapter Tube - 1" O.D. x 3 1/16" x 21 Ga.	.35
19213	Cast Iron Cylinder R.H. - 2 3/4" Bore	12.00
19214	Cast Iron Cylinder L.H. - 2 3/4" Bore	12.00
19216	Piston - 2 3/4" Bore	3.75
19217	Piston Ring - Compression 3/32" x 2 3/4"	.35
19218	Piston Ring - Oil 3/16" x 2 3/4"	.50
19220	Connecting Rod - Cast. Alum.	3.75
19221	Washer for Connecting Rod Bolt	.05
19232	Oil Gauge Gasket - Neoprene	.25
19242	Stud for Oil Base	.15
19244	Stud for Cylinder Base	.15
19248	Breather Tube	1.25
19249A	Breather Tube Screen Assembly	.75
19272	Intake Manifold	2.25
19276	Oil Base Gasket	.20
19285	Oil Base - Cast Alum	6.50
19297	Oil Filler Cap	.40
19297B	Oil Filler Cap Gasket	.10
19298	Oil Level Gauge	.35
19301	Gearcase Gasket	.25
19304	Gearcase - Cast Alum	4.50
19330L	Blower Housing Baffle - Left Hand	1.50

OTC ENGINE PARTS LIST

PART NO.	PART NAME	APPROXIMATE VALUE, EACH
19330R	Blower Housing Baffle - Right Hand.	$ 1.50
19331	Blower Housing Grille	.75
19332	Blower Housing Grille Clip.	.10
19334	Blower Housing Only	10.00
19335	Cylinder Air Housing - R.H.	2.75
19336	Cylinder Air Housing - L.H.	2.75
19340	Ignition Breaker Plate.	.95
19341	Ignition Breaker Plate Cover.	.75
19342	Breaker Plate Mounting Strip.	.20
19343	Contact Strip Insulator	.15
19344	Breaker Plunger	.25
19402	Magneto Wheel Bolt.	.25
19403	Magneto Wheel Assembly.	10.00
19410	Duplex Magneto Back Plate	.85
19411	Magneto Condenser .5 MFD	.75
19412	Magneto Coil - Left Side of Engine.	2.40
19413	Spark Plug Cable - L.H.	.65
19414	Spark Plug Cable - R.H.	.65
19415	Magneto to Breaker Condenser Lead	.25
19416	Magneto Primary Stop Wire - Manual.	.20
19417	Magneto Primary Stop Wire - S.S	.20
19450	Gas Tank.	8.00
19452	Gas Tank Cap.	.50
19453	Shut-Off Screw for Filler Cap	.35
19454	Gasket for Filler Cap	.10
19455	Gasket for Shut-Off Screw	.05
19457	Spring for Shut-Off Screw	.10
19475	Fuel Pump - AC Type W (GP9200).	7.50
19476	Fuel Pump Gasket.	.10
19477	Fuel Pump Push Rod.	.40
19478	Fuel Pump Adapter - Cast Alum	1.25
19479	Fuel Pump Adapter Gasket.	.10
19480	Fuel Pump Bowl Gasket	.10
19483	Fuel Line - Fuel Pump to Carburetor - 1/4" x 9 3/8" Copper Tube	1.25
19484	Fuel Line - Fuel Tank to Fuel Pump - 1/4" x 16¼" Copper Tube.	2.25
19708A	Outlet Box Assembly - with 2 Receptacles #76800	3.00
19802	Carburetor (Zenith)	12.00
19850	Spark Plug - #43.	.65
19862	Exhaust Muffler	8.00
19952	Air Cleaner	2.00
19953	Air Cleaner Adapter	1.00
19971	Complete Chassis Assembly	12.00
75863	Governor Ball Joint	.50
76775	Pipe Nipple - 3/8" Close - Filter Bowl to Fuel Tank	.10
76776	Pipe Coupling - 3/8".	.15

GENERATOR PARTS LIST

PART NO.	PART NAME	APPROXIMATE VALUE, EACH
842	Brush Spring - D.C.	$ .25
1160	Brush Guide - D.C	.50
1261	Armature Ball Bearing - Hoover #7205.	3.00
2535A	Collector Ring Assembly	6.00
15360	A.C. Line Filter Condenser - .1 MFD	.50
15649	A.C. Brush - 9/32" x 7/8" x 1 5/32" M46	.60

GENERATOR PARTS LIST

PART NO.	PART NAME	APPROXIMATE VALUE, EACH
15650	A.C. Brush Guide - 9/32" x 7/8" Brush.	$ .50
15681	Rope Sheave with Blower Fins	2.50
15651A	A.C. Brush Holder & Bracket Assembly	.85
19021	Bearing Plate & Generator Support.	3.50
19508	Generator Through Stud Nut	.25
19520	Armature Through Stud Nut.	.35
19521	Armature Through Stud Nut Washer	.10
19577	Generator Frame Assembly with Field Coils.	50.00
19567	Armature Assembly.	50.00
19569	Armature Through Stud	.35
19570	Generator Through Stud	.25
19578	Generator Blower	2.50
19631	Field Coil Set - Complete.	20.00
19649	Commutator - 25 Bar.	6.00
19653	A.C. Brush Spring.	.25
19655	Brush Guide Insulator Ring	.75
19655A	Brush Rig Assembly	6.50
19657	A.C. Connector Bracket	.10
19662	A.C. Brush Connector Wire. (2 used)	.35
19676	Generator Grease Cover	.25
19677	Generator Grease Cover Gasket.	.10
19682	Generator End Bell Band.	.60
19694	Generator End Bell Housing	4.50
75260	Pole Shoe Assembly	2.00
75349	D.C. Brush - 1/4" x 5/8" x 1 1/4" M46.	.25

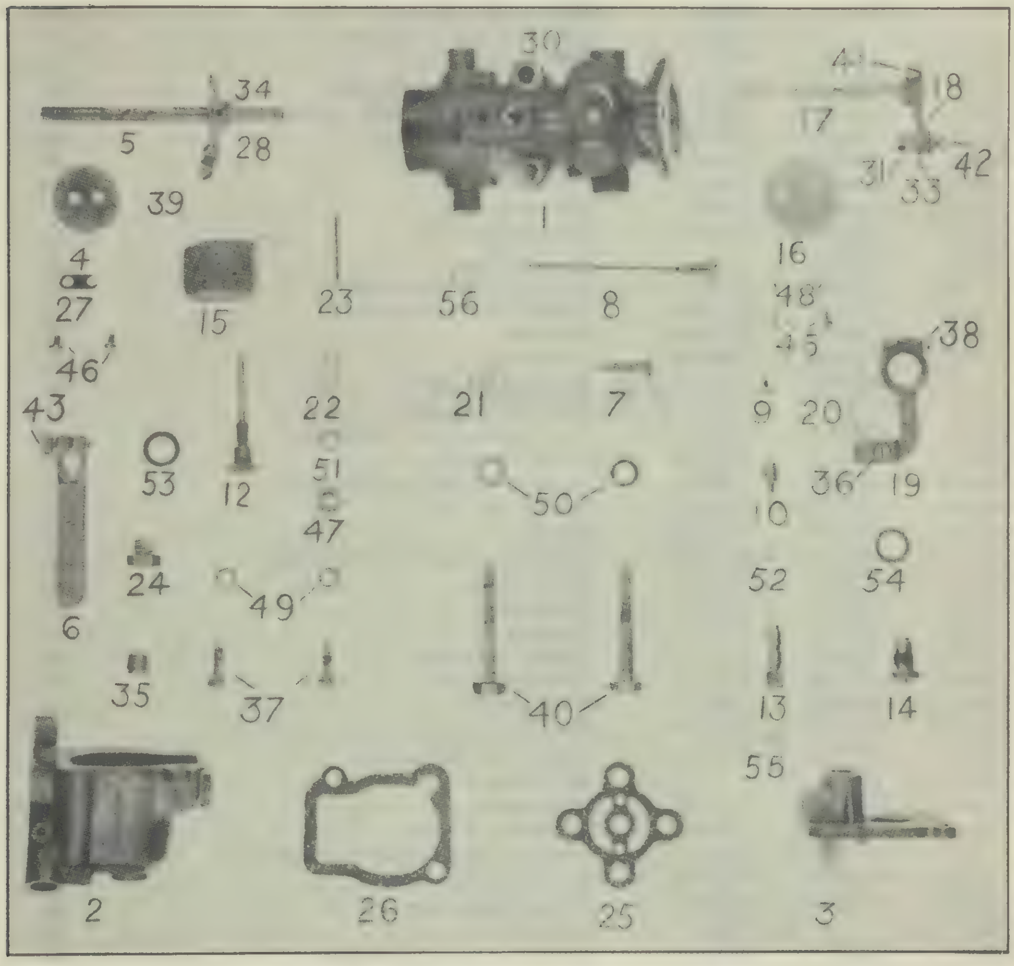
CARRYING CASE PARTS LIST

PART NO.	PART NAME	APPROXIMATE VALUE, EACH
19905	Carrying Handle. (2 used)	$ .50
19911	Side Panel - L.H	9.50
19912	Side Panel - R.H	9.50
19914	Tool & Spare Parts Box	3.50
	1 Set Spare Tools and Wrenches	6.50
19915	Plant Clamp Bracket. (2 used)	1.25
19916	Wing Nut - 5/16" (4 used)	.15
19918	Trunk Clasp. (14 used)	.75
19919	Harness Snap & Chain Assembly. (14 used)	.75
19992	Wire Compartment Slide Cover	7.50
19993	Top Panel - Wire Compartment	10.50
19994	Back Panel	12.50
19995	Front Panel.	12.50
76839	Grounding Cable - 5 Ft. #10 AWG Rubber Covered	1.25
76840	Power Cable - 51 Ft. #12 - 3 Conductor AWG Rubber Cover Type S.	15.00
76841	Angle Cord Connector	.60
76842	Angle Cord Plug.	.60
76843	Spring Clips.. (2 used)	.25
76844	Grounding Rod.	2.25

PARTS PRICE LIST

for

ZENITH TU-SERIES CARBURETORS



Use Gasket Set C181-44 . . . . . . List Price $0.45

When ordering parts for TU-Series Carburetors, it is imperative that the number appearing on the identification plate of the Carburetor be given

Ref. No.	TU3 Part No.	TU3½ Part No.	TU4 Part No.	PART NAME	TU3 List Price	TU3½ List Price	TU4 List Price
1	B2-9	B2-4	B2-5A	Throttle body assy. (Venturi is cast-in, specify size wanted)	$6.50	$5.00	$5.00
1	B2-2A	B2-4D		Throttle body assy. (used on TU3Y, TU3½X only) (Venturi is cast-in, specify size wanted)	4.00	4.50	
2	B3-7	B3-30	B3-30	†Fuel bowl assy (4 hole type)	2.00	2.00	2.00
3	C6-3A	C6-3A	C6-3A	*†Fuel bowl cover assy. (4 hole type)	.75	.75	.75
3	C6-3C	C6-3C	C6-3C	*Fuel bowl cover assy. (For Main Jet Adjustment)	.75	.75	.75

†NOTE—The 2 hole type Fuel Bowl and Cover are no longer available. To replace either part it is necessary to order both the Fuel Bowl and the Cover of the new 4 hole type.

Ref. No.	TU3 Part No.	TU3½ Part No.	TU4 Part No.	PART NAME	TU3 List Price	TU3½ List Price	TU4 List Price
4	D8968	C21-2	C21-2	Throttle plate	$ .30	$ .90	$ .90
5	C23-7	C23-35	C23-2	Throttle shaft	.50	.50	.40
6	C24-42	C24-7x2	C24-7x2	Throttle lever	.75	.85	.85
7	C46-25	C46-25	C46-25	Idle adjusting screw	.30	.30	.30
8	C51-4	C51-2	C51-2	Idling Jet (specify size)	.75	.75	.75
9	C52-2	C52-2	C52-2	Compensator (specify size)	.35	.35	.35
10	C52-1	C52-1	C52-1	*Main jet (specify size)	.35	.35	.35
11	....	....	C63-3	Pitot tube (not illustrated)	...	...	.10
12	C73-7	C73-7	C73-7	*Main jet adjustment	.90	.90	.90
13	D9059	C76-3	C76-2	Metering well (specify size)	.35	.75	.75
14	C81-2	C81-2	C81-2	Fuel valve and seat assy. (specify size)	.60	.60	.60
15	C85-15	C85-15	C85-15	Float assy. (Metal Body)	.60	.60	.60
16	D8967	C102-4	C102-3	Air shutter	.25	.15	.15
17	C105-10	C105-4	C105-3	Air shutter shaft	.50	.40	.50
18	CR106-4	CR106-4	C106-2	Air shutter lever	.30	.30	.25
19	C109-3	C109-3	C109-2	Air shutter bracket	.35	.35	.35
20	C110-1	C110-1	....	Bracket clip	.05	.05	...
21	C111-9	C111-9	C111-9	Idle adjusting screw spring	.10	.10	.10
22	C111-62	C111-62	C111-62	Throttle stop screw spring	.10	.10	.10
23	C121-14	C121-14	C121-14	Float axle	.10	.10	.10
24	C138-23	C138-23	C138-23	Lower plug	.35	.35	.35
25	C142-2	C142-2	C142-2	Bowl to body gasket	.10	.10	.10
26	C144-1-1	C144-1-1	C144-1-1	Bowl to cover gasket (4 hole type)	.10	.10	.10
27	CR22-1	CR22-1	CR22-1	Throttle plate screw lockwasher	.10	.10	.10
28	C28-27	CR28-7	CR28-22	Throttle stop lever	.50	.65	.45
29	D8963x2	CR66-4	CR66-4	Discharge nozzle (not illustrated)	.35	.75	.75
30	CR121-11	CR121-11	CR121-11	Throttle stop pin	.05	.05	.05
31	CR134-2	CR134-2	CR134-1	Swivel	.20	.20	.20
32	CR137-13	CR137-13	CR137-13	Stop pin hole plug (not illustrated)	.05	.05	.05
33	CT52-1	CT52-1	CT52-1	Swivel washer	.05	.05	.05
34	CT63-2	CT63-2	CT63-2	Taper pin	.05	.05	.05
35	CT91-1	CT91-1	CT91-1	Pipe plug	.10	.10	.10
36	T1S8-8	T1S8-8	....	Bracket clip screw	.05	.05	...
37	T1S10-8	T1S10-8	T1S10-8	Cover assy. screw	.05	.05	.05
38	T1S10-10	T1S10-10	C140-2	Bracket screw	.05	.05	.05
39	T1S10-14	T1S8-10	T1S8-10	Throttle stop screw	.05	.05	.05
40	T2S25-28	T2S25-28	T2S25-28	Bowl to body screw	.10	.10	.10
41	T8S8-7	T8S8-7	....	Air shutter lever screw	.05	.05	...
42	T8S8-10	T8S8-10	T1S8-6	Swivel screw	.05	.05	.05
43	T8S10-9	T8S10-9	T1S10-7	Throttle lever screw	.05	.05	.05
44	....	....	T10-1	Pitot tube clamp screw (not illustrated)	...	...	.05
45	T15B5-3	T15B5-3	T15B5-3	Air shutter plate screw	.05	.05	.05
46	T15B5-3	T15B5-3	T15B5-3	Throttle plate screw	.05	.05	.05
47	T22S8	....	T22S8	Shaft nut	.05	...	.05
48	T41-5	T41-5	T41-5	Air shutter screw lockwasher	.05	.05	.05
49	T41-10	T41-10	T41-10	Cover screw lockwasher	.05	.05	.05
50	T44-25	T44-25	T44-25	Bowl to body screw lockwasher	.05	.05	.05
51	T45-8	....	T45-8	Shaft nut lockwasher	.05	...	.05
52	T56-4	T56-4	T56-4	Main jet washer	.05	.05	.05
53	T56-23	T56-23	T56-23	Lower plug washer	.05	.05	.05
54	T56-23	T56-23	T56-23	Fuel valve seat washer	.05	.05	.05
55	T56-24	T56-24	T56-24	Metering well washer	.05	.05	.05
56	T56-48	T56-48	T56-48	Idle jet washer	.05	.05	.05
57	...	C112-6	C112-6	Air shutter spring (not illustrated)	...	.10	.10
58	C111-21	C111-21	C111-21	*Main jet adj. spring (not illustrated)	.10	.10	.10
59	CT51-1	CT51-1	CT51-1	Main jet adj. washer (not illustrated)	.05	.05	.05

*When main jet adjustment is used, use C6-3C bowl cover and C59-2 main jet. For complete adjustment assembly, including C73-7 adjustment, C59-2 main jet, C111-21 spring and CT51-1 washer, order C73-17 main jet adjustment assembly, List Price $1.10, and specify size of main jet required. A main jet two sizes larger than that now being used is recommended for use with the main jet adjustment.

GLOSSARY

A. C.
An abbreviation for alternating current.

A. I. E. E.
An abbreviation for "American Institute of Electrical Engineers."

A. W. G.
An abbreviation for "American Wire Gauge."

ACID PROOF PAINT
A paint that resists the action of acids, for example the sulphuric acid used with storage batteries. In the Dark Room of an X-ray Department, the action of the fixing solutions on the bench tops, tanks, walls, etc.

ADJUSTABLE RESISTANCE
A resistance whose value may be adjusted, or a resistance arranged so that more or less of it may be inserted in a circuit.

AERIAL CIRCUITS
Conductors or wires supported in the air - from ceilings as distinguished from under ground systems.

AFTERGLOW
That characteristic possessed by intensifying screens which allows X-ray energy to remain momentarily in the screen after the X-ray exposure has been terminated.

AGING OF MAGNET
A gradual loss of magnetism that takes place following the magnetizing of a permanent magnet. It is rapid at first, but gradually becomes slower and slower.

AGING OF TRANSFORMER
A gradual loss of efficiency that takes place in a transformer due to changes in the iron of the core.

AIR COOL
To cool a device solely by the circulation of a current of air.

AIR CUSHION
A device for diminishing shock by compressed air.

AIR DIELECTRIC
The value of air as a dielectric is taken as 1, and the value of other dielectrics are based on a comparison with the value of air.

AIR GAP
The air space between the ends of conductors.

AIR INSULATION
The use of air as an insulator, with or without additional insulation of other material.

ALIVE
Carrying an electric current or voltage.

ALLOY
A metal composed of two or more metals or of metals and other material melted together in order to produce some desired result in the alloy.

ALTERNATING CURRENT
An electric current which reverses its direction of flow at regular intervals, many times each second. Abbreviated A.C. If a closed wire is placed in an expanding magnetic field, the current induced in the wire by the changing field will flow in such a direction that the magnetic field set up in turn by this induced current opposes the field which originally caused it. Now if the original field is caused to collapse, the induced current will change its direction so that its field again will be in opposition to the original field. If the primary field regularly builds up and collapses, the current will change direction correspondingly; in other words, it is an alternating current. Since current is only caused to flow by a changing magnetic field, it is easy to see why alternating currents are widely used; they are the result of the application of the principle of induction.

ALTERNATING CURRENT GENERATOR
A generator producing alternating currents.

ALTERNATING CURRENT INSTRUMENTS
Instruments which measure or record the various values of alternating currents such as voltage, amperage, phase, frequency, etc.

ALTERNATING CURRENT RECTIFIER
A device for changing alternating current into direct current by electrical, mechanical or chemical action.

ALTERNATION
One half cycle of an alternating current.

ALTERNATOR
A generator which produces an alternating current.

ALTITUDE
As altitude is increased the spark over distance is increased at same voltage.

AMBIENT TEMPERATURE
The temperature of the air or other medium surrounding the heated parts of an electrical device.

AMERICAN WIRE GAUGE
The gauge generally adopted and used for measuring the size of wires in United States.

AMMETER
An instrument which measures and indicates the number of amperes flowing in an electric circuit (X-ray tube filament circuit). An ammeter or milliamperemeter is connected in series with the circuit in which current is being measured, so that the current flows through the instrument.

AMMETER SHUNT
A low resistance conductor placed in parallel or shunt with an ammeter so that the greater part of the measured current flows through the shunt, only a

small part of the total flow going through the ammeter itself.

AMPERAGE
The strength of an electric current in amperes.

AMPERE
The practical unit for measurement of electric current; the electric current that flows through a circuit having a resistance of one ohm when the pressure is one volt.

AMPERE HOUR
A measure of quantity of electricity: The quantity that flows through a circuit in one hour when the flow is one ampere.

AMPLIFICATION
Enlargement.

AMPLIFIER
A device by which weak currents or sounds acting on another circuit are increased in strength.

ANALOGY
A similarity in action between two different things such that one may be more easily understood by comparison with the other.

ANESTHESIA
Loss of feeling or sensation, especially loss of tactile sensibility, though the term is used for loss of any of the other senses.

ANGSTROM UNIT
A unit of measure of light or x-ray wave lengths. It is equivalent to $\frac{1}{100,000,000}$ of a centimeter, one-tenth of a millimicron, or one two-hundred and fifty-four millionth of an inch.

ANNEAL
To soften by heating and allowing to cool slowly.

ANODE
The positive pole of any electric source.

ANTISEPTIC
A substance that will prevent growth of bacteria.

ARCING OF BRUSHES
Sparks occuring at the contact between a brush and its commutation or slip ring on a motor for example.

AREA OF CONDUCTOR
The size of a section through a conductor. usually measured in circular mils.

ARGON
A colorless, odorless, inert gas which forms a part of the air. It is used in the bulbs of certain types of rectifiers.

ARGON BULB RECTIFIER
An alternating current rectifier using a bulb with a tungsten filament and

filled with argon gas through which the current can pass in one direction only.

ARMATURE
The part of a generator or motor that rotates between the field poles and which carries windings in which electro-motive force acts for the operation of the machine.

ARMATURE COIL
A coil of wire placed on the armature of a generator or motor, part of the armature winding.

ARMATURE CORE
The iron cylinder or ring on which, or in which, armature windings are carried.

ARMORED CABLE
Conductor cable having a woven or spirally wound metallic covering over its insulation so that it is protected against mechanical injury. In the field this type of cable is frequently referred to as B.X.

ARTIFICIAL MAGNET
A manufactured permanent magnet.

ASBESTOS INSULATED WIRE
Wire whose insulation is protected against high temperatures by a covering of asbestos.

ASEPTIC
Free from harmful organisms.

ASPIRATOR
A mechanical device for producing a vacuum.

ATMOSPHERE
The pressure of air; a pressure of one atmosphere is equal to 14.7 pounds per square inch.

ATOM
The smallest particle of an element that can exist alone or in combination with like atoms or with atoms of other elements. Some 90 odd different atoms have been recognized, which in combination with one another or others like themselves make up all the various types of material entities, being themselves composed of still smaller particles called electrons and protons.

ATOMIC WEIGHT
The weight of one atom of an element as compared to the weight of an atom of hydrogen.

ATTRACTION
The effect between magnetized bodies or between a magnet and iron or steel by which they are drawn together.

AUTOCLAVE
A type of pressure sterilizer.

AUTOMATIC
Having the power of self action.

AUTOMATIC CIRCUIT BREAKER
A circuit breaker operated by the current in the circuit to be broken.

AUTO TRANSFORMER
A transformer in which part of the winding is in both the primary circuit and the secondary circuit used to boost or reduce line voltage for voltage correction, control, etc. A transformer in which the primary and secondary are combined.

AUXILIARY CIRCUIT
Circuits not regularly used for power, light, etc., but used for control purposes, for instruments, etc.

B.W.G.
An abbreviation for "Birmingham Wire Gauge."

B. & S.
An abbreviation for "Brown & Sharpe" wire gauge. It is the same as the American wire gauge.

B.T.U.
British Thermal Unit.

BACILLI
Bacteria shaped like a rod or stick.

BACTERIA
An important and widely distributed group of microscopic, one celled, vegetable organisms.

BAKELITE
A moulded insulating material having a phenol base.

BALLISTIC METER
An ammeter having a weighted needle used to measure milliampere seconds - the product of milliamperes and (split second exposures) time.

BAROMETER
An instrument for measuring atmospheric pressure.

BASES
Compounds of an alkaline character in solution, capable of reacting with acids to form salts and water; specifically the Hydroxide of a positive element or radical.

BATTERY
A group of cells or often a single cell producing an electric current.

BINDING POST
A screw terminal for connecting the ends of wires to electrical parts or circuits.

BIPOLAR
The use of two poles in electrotherapeutic treatments. When referring to an

alternating current, the term "biterminal" should be used.

BIRMINGHAM WIRE GAUGE
A wire gauge often used in telegraphic and telephone work.

BLOW
To "blow-out" a fuse, to burn out a wire, etc.

BOOSTER TRANSFORMER
A transformer used to raise the voltage of alternating current.

BREAK DOWN OF INSULATION
Failure of insulation so that current passes through it. Caused by too high voltage, by cracks and holes, or by rotting and decay.

BRITISH THERMAL UNIT
The amount of heat that increases the temperature of one pound of water one degree Fahrenheit.

BRONZE
An alloy of copper and tin, used for conducting parts in switches, etc.

BRUSH
A conductor, of metal or carbon, that rests against the moving surface of a commutator or slip ring for the purpose of allowing current flow between the two parts.

BUCKING
Opposing one action by another of similar kind but opposite in effect.

BUCKING COIL
A winding or coil on an electromagnet or a field winding which opposes the magnetism produced by the main windings.

BURN OUT
Melting through of an electrical conductor due to heating effect of an excessive current.

BUS BAR
A heavy rod or bar of copper, brass, or bronze, carrying one of the main circuits on a switch board or between distributing points.

BX CONDUCTOR
An electrical cable covered with a spirally wound steel strip for mechanical protection.

C. An abbreviation for "Centigrade" thermometer scale.

C. A symbol, meaning capacity, expressed in farads.

C. A symbol formerly used for amperes or current; now replaced by the symbol "I".

C.C.W.
An abbreviation for "counter clockwise" rotation.

C. P.
An abbreviation for "candle power", also used for "constant potential".

C. W.
An abbreviation for "clockwise" rotation.

CABLE
A conductor composed of a number of separate conductors; a stranded conductor.

CABLE BOX
An enclosure in which joints and connections are made between cables for different circuits.

CABLE CLAMP
A round clamp for attaching cables to their support.

CABLE CLIP
A half round clamp for holding a cable against a flat surface.

CABLE SHIELD
A piece of metal which protects a cable where it passes through an opening.

CALIBRATE
To compare the readings of a measuring instrument with some fixed standard or with another instrument and note or correct any variation from the correct readings.

CALIBRATION
The determining of the KVP value of each auto transformer tap at various milliamperages to be used, checking these values by means of a sphere gap and a pre-reading voltmeter, or other accepted methods.

CALORIE
A unit of heat in the metric system.

CAMBRIC TAPE
Tape made of cotton treated with linseed oil.

CANDLE; FOOT
The amount of light from a standard candle one foot away.

CANOPY
An overhanging covering.

CAPACITANCE
The ability to receive or carry a charge of electricity; the ratio between the charge and the voltage that causes it. Measured in farads and microfarads.

CAPACITY
The load which will cause any electrical device to reach some specified condition, such as a certain temperature, a certain voltage, etc.

CAPACITY OF CONDENSER
The amount of electricity (the electric charge) that a condenser will receive

and hold. Measured in farads or microfarads.

C A R B O N
One of the elements used in electrical work for making brushes, electrodes, contacts, etc. It is a fair conductor and withstands heat and sparking.

C A R B O N   F I L A M E N T   L A M P
An incandescent electric lamp using a filament of carbon. It is not as efficient as lamps with tungsten filaments, but the carbon is not so easily broken. An old style of lamp.

C A R B O N I Z E
To turn other material into carbon.

C A R T R I D G E   F U S E
A fuse enclosed in a tube of fiber or glass so that there is no exposed flash when the fuse burns out.

C A T H E T E R
A tube for introduction through a narrow canal into a cavity.

C A T H O D E
The negative terminal of an electrical apparatus.

C A T H O D E   R A Y S
A stream of electrons leaving the cathode in a discharge tube.

C A U T E R Y
An instrument for burning, with white hot iron or wire.

C E L L U L O I D
A material made from gun-cotton and oil. It forms a good insulator but takes fire easily.

C E N T I G R A D E
A thermometer scale having a freezing point at 0 and a boiling point at 100.

C E N T I M E T E R
One hundredth part of a meter. Approximately two-fifths of an inch, 0.3937 of an inch.

C H A R G E
The electricity held in a static condition by a condenser or a conductor having capacity.

C H O K E   C O I L
A coil having high inductance but low ohmic resistance, used in A.C. current circuits to limit the flow of current. A reactor or reactance coil.

C I R C U I T
The complete path through which the current flows, or, a certain part of the complete part such as one of its conductors.

CIRCUIT BREAKER
A form of switch, usually automatic in action, which opens a circuit under abnormal or dangerous conditions in the circuit. An automatic current limiting device which may be used by hand. Used to prevent overload of a circuit.

CIRCUITS, SERIES
The linking together of two circuits so that same current travels through both circuits.

PARALLEL - One circuit connected across another.
OPEN - No current passes. Interrupted.

CIRCULAR MIL
The area of a circle, one thousandth of an inch, or one mil in diameter.

CLOSED CIRCUIT
An electric circuit that is complete and through which current may flow when voltage is applied.

CLOSED MAGNETIC CIRCUIT
A magnetic circuit formed entirely of iron or steel all the way around. Some devices having a very small air gap are also said to have closed magnetic circuits.

COAGULATE
To thicken.

COCCUS
A bacterium shaped like a berry.

COEFFICIENT
A number which indicates the rate or amount of change in some condition, such as resistance, that is brought about by other changing conditions.

COIL
An insulated wire wound in a spiral.

COLLECTOR RING
A metal ring connected to the windings of an A.C. armature and through which current is taken by a collector brush to the circuits.

COMMUTATOR
A ring of copper segments insulated from each other and connected to the windings of an armature. The alternating impulses from the armature conductors are passed by the commutator into the brushes so that current flowing through any one brush is always in the same direction.

COMPENSATOR
A correcting device.

COMPOUND
A substance formed by two or more elements.

CONDENSE
To reduce from a gas or vapor to a liquid.

CONDENSER
A device having the ability to receive and hold an electric charge in two conductors separated from each other by insulation, called the di-electric, through which the two condensers exert an inductive effect. A condenser is sometimes called a "capacity". The purpose of condensers is to absorb electricity across the make and break contacts, thereby lessening sparking, which in turn lessens the burning or destruction of the contact points.

They are commonly used in the oscillatory circuit for the generation of high frequency current of high frequency apparatus.

CONDENSER CAPACITY
The amount of electric charge a condenser will receive and hold. Measured in farads and microfarads.

CONDENSER CHARGE
The electricity held in the plates of a condenser.

CONDENSER DIELECTRIC
The insulating material between the plates of a condenser, usually mica, paper, glass or air.

CONDENSER PLATE
One of the conductors in a condenser or the whole number of conductors that are connected together on one side of the circuit.

CONDUCTANCE
The conducting power of a body or a circuit for electricity. The best conductor is that which offers the least resistance. Examples of good conductors are gold, silver and copper. When expressed in figures, conductance is the reciprocal of resistance. The unit is the mho.

CONDUCTIVITY
The specific electric conducting power of a substance. Numerically, conductivity is the reciprocal of unit resistance, or resistivity. The unit is the mho per cm. Specific conductivity is sometimes expressed as a percentage. In such cases the conductivity is given as a percentage of the conductivity of pure copper under certain standard conditions.

CONDUCTOR
A wire or other path through which electric current may flow with comparatively little resistance.

CONDUIT
Flexible or rigid tubing of metal or other material in which the electrical conductors are placed to protect them against injury and to protect surrounding parts against the effect of escaping current.

CONDUIT BOX
A box between the ends of lengths of conduit and in which connections are made between the conductors.

CONDUIT BUSHING
A threaded sleeve which screws over the end of a conduit to hold it in a conduit box.

C O N D U I T   B U S H I N G   A D A P T E R
A threaded sleeve which allows the use of small conduit with larger fittings or large conduit with smaller fittings.

C O N D U I T   C O U P L I N G
A metal piece that screws over the end of a conduit and into which another piece of conduit can be screwed to hold conduits end to end.

C O N D U I T   E L B O W
A threaded metal sleeve with its two ends bent at any angle so that lengths of conduit may be joined at this angle.

C O N J U N C T I V I T I S
Inflammation of the membrane lining of the eyelid.

C O N N E C T I O N
The state of being joined.

C O N S T A N T   C U R R E N T
An unchanging flow of amperage in a circuit.

C O N S T A N T   P O T E N T I A L
Constant voltage, an unchanging voltage under various conditions of speed and load.

C O N T A C T
A point through which current flows to another contact or conductor when they are held together, and at which the circuit is opened when the contacts are separated.

C O N T A C T O R
A device which opens and closes a circuit for the operation of electrical parts.

C O N T I N U O U S   C U R R E N T
A direct current of constant value, without appreciable rise or fall.

C O N V E R T E R
An electrical device with rotating parts which changes a current of one kind into a current of another kind.

C O O L I D G E   T U B E
An x-ray tube using a tungsten filament which is heated to permit the flow and control of electrons with comparative ease.

C O P P E R
The metal most commonly used for electrical conductors because of its relatively low resistance.

C O P P E R   L O S S
The power loss in overcoming the resistance of conductors.

C O R O N A
An electrostatic discharge causing a violet light around conductors carrying high voltage. It occurs just before the voltage rises high enough to cause a spark or a steady brush discharge.

C O U L O M B
A measure of electrical quantity. The quantity of electricity passing through a circuit in one second when the flow is one ampere. An ampere second.

C O U N T E R E L E C T R O M O T I V E F O R C E
A voltage or electromotive force which opposes the normal or impressed voltage in a circuit and which sends current in the opposite direction.

C R I T I C A L D A M P I N G
Damping of an electrical measuring instrument so that its needle returns to zero without moving back and forth across zero.

C U R R E N T
The rate of flow of electricity in a circuit. Current measurement in amperes.

C U T O U T
In electrical work, a fuse.

C Y C L E
One complete wave of an alternating current, from zero to positive maximum, to negative maximum, and back to zero. Two alternations. The travel of a current wave thru its maximum positive and negative value.

Frequency - Term denoting number of cycles per second.

Commonly	furnished	at	60	cycles	per	second
"	"	"	50	"	"	"
"	"	"	25	"	"	"

Equipment designed for 50 cycle will function on 60 cycle line.

25 cycle equipment should be used on that frequency only.

D . C .
An abbreviation for "direct current".

D . P .
An abbreviation for "double pole".

D . P. S . S .
An abbreviation for "double pole snap switch".

D . T .
An abbreviation for "double throw".

D . P . S . T .
An abbreviation for "double pole single throw".

D . P . D . T .
An abbreviation for "double pole double throw".

D A M P E D N E E D L E
In an electric measuring instrument, a needle that quickly comes to rest.

D A M P I N G O F I N S T R U M E N T
The degree of damping is determined according to the time it takes the

pointer of an instrument to come to rest, according to the number of swings the pointer makes back and forth, and according to the distance beyond the true reading to which the pointer swings.

D'ARSONVAL METER
A voltmeter or ammeter whose pointer is attached to wire carried between the poles of a permanent magnet.

DEAD BEAT
An instrument whose pointer comes immediately to its true reading without swinging back and forth.

DE-ENERGIZE
To stop current from flowing in a circuit or an electrical part.

DEFLECTION
The movement of the indicating pointer of an electric measuring instrument.

DELTA CONNECTION
Connection of three alternating current windings or circuits with the end of each one connected to the beginning of the next, forming a triangular connection.

DEMAGNETIZATION
Causing the magnetism to disappear from a magnet. An electromagnet is demagnetized by stopping the current through its windings or by reversing the current. A permanent magnet is demagnetized by heating, or hammering, or by the effect of another magnet.

DEMAND
The amount of electric power required from a circuit or source.

DEMAND FACTOR
The ratio of the greatest demand in a given time to the total connected load.

DIAPHRAGM (ANATOMICAL)
The muscular partition separating the thorax and abdomen. (Physical) a vibrating disc; (x-ray) a slotted device to regulate the admission of x-ray.

DIATHERMY
A term employed to designate the use of a high frequency current to generate heat within some part of the body. The frequency (rate of oscillation or alternation) of the current ranges from approximately 750,000 to more than 3,000,000 oscillations per second. When such a current is passed through the body at a sufficient voltage and amperage, the resistance offered by the tissues intervening between the electrodes causes heat to be generated in such tissues. It was d'Arsonval who demonstrated that the passage of high frequency electrical currents through living tissues causes neither direct nor indirect contraction of muscles but does cause the tissues to become heated. Nagelschmidt of Berlin, in 1907, apparently was the first to apply this property to human beings for therapeutic purposes, and to give it the name of diathermy - "heating through". The rise in temperature depends not only on the amount of energy absorbed but also on the efficiency of the circulation in carrying off the heat and maintaining normal temperature.

DIELECTRIC
An insulating material through which induction can take place; an insulator.

D I E L E C T R I C   C U R R E N T
The current that apparently passes through the dielectric of a condenser in an alternating circuit.

D I E L E C T R I C   S T R E N G T H
The ability of an insulating material to resist electric potential or voltage. Measured in the number of volts required to puncture a given thickness.

D I F F E R E N C E   O F   P O T E N T I A L
The difference of voltage or pressure between two points.

D I R E C T   C U R R E N T
Abbreviated D. C.; an electric current flowing always in the same direction through a conductor.

D I R E C T   C U R R E N T   C O N V E R T E R
A converter changing a direct current of one voltage to a direct current of another voltage.

D I R E C T   C U R R E N T   I N S T R U M E N T S
Measuring and indicating instruments suitable for use only with direct currents.

D I S C H A R G E
A passage of electricity from a source.

D I S T R I B U T I O N   P A N E L
A panel or switchboard on which connections are made between main supply circuits and branch lines.

D O U B L E - B R E A K   K N I F E   S W I T C H
A switch breaking two contacts at the same instant.

D O U B L E - C O N T A C T   L A M P
A lamp whose base and socket are designed for use on a two-wire system with both sides of the circuit insulated.

D O U B L E   F I L A M E N T   L A M P
An incandescent lamp containing two separate filaments, one for low candlepower, the other for higher candlepower.

D O U B L E   F I L A M E N T, X - R A Y   T U B E
An x-ray tube having two separate filaments, one for low milliamperage, thus greater detail; the other large, for comparatively higher milliamperage and rapid exposure work.

D O U B L E   P O L E
Connected to both sides of a circuit, or arranged for connecting into two circuits.

D O U B L E   R E D U C T I O N
A drive operating through two sets of gears, belts, or chains so that the total reduction in speed is equal to the product of the two reductions.

D O U B L E - T H R O W   S W I T C H
A knife switch whose blades are pivoted at the center of the switch and arranged to make contact with connections at either one end or the other of the

switch so that a circuit may be completed through either of the two paths.

DROP WIRE
The connection from the outside line to the building.

DROP OF POTENTIAL
A decrease of electric potential or voltage from place to place in a circuit.

DRY CELL
A primary electric cell using carbon and zinc for electrodes with an electrolyte of sal-ammoniac and chloride of zinc carried by some absorbent material in the cell. The carbon is the positive electrode and the zinc is the negative.

DUPLEX CABLE
A cable made of two wires insulated from each other and both carried in an outside insulation.

DYNAMO
Usually a generator. However, the term is occasionally used to describe a motor.

E.
A symbol for voltage.

E. M. F.
An abbreviation for "electromotive force".

EARTH WIRE
A connection to the earth; the earth considered as a common part of all electrical circuits. The word earth has the same meaning as ground.

EBONITE
Black hard rubber.

EDDY CURRENT
An electric current produced in the iron or steel cores of fields and coils by the changing electromagnetic force in the iron, which is a conductor.

EFFECTIVE CURRENTS
The value of an alternating current or of a pulsating direct current, that would be shown by a steady reading ammeter in the circuit.

EFFECTIVE RESISTANCE
The resistance to alternating current. It includes the ohmic resistance and all other electrical and inductive losses.

EFFICIENCY
The ratio of the useful work or output of an electrical device to the power supplied to it.

ELASTANCE
The opposite of capacity in a condenser, the opposite to taking an electric charge, "electrostatic resistance."

ELECTRIC ATTRACTION
The attraction for each other possessed by bodies or conductors carrying an electric current or charge.

ELECTRIC ENERGY
The ability of electricity to perform work, to develop work.

ELECTRIC GLOW
Corona.

ELECTRIC HEATER
A heater using resistance wire made hot by a flow of current through it.

ELECTRIC HORSEPOWER
Horsepower measured in watts. 746 watts equal one electrical horsepower.

ELECTRIC POTENTIAL
Pressure, Voltage.

ELECTROCAUTERY
An apparatus for cauterizing tissue, consisting of a holder containing a platinum wire, which may be heated to a red or white heat by a current of electricity, either direct or alternating.

ELECTRODE
A terminal of an electric source or the conductor through which current enters or leaves the electrolyte.

ELECTRODYNAMIC
Relating to the electric current, electricity in motion. Relating to the actions and effects of magnetism and induction.

ELECTRODYNAMIC INDUCTION
Production of an induced current in a conductor by change or movement of a magnetic field or the conductor. Includes self-induction, mutual induction, and electromagnetic induction.

ELECTROLYSIS
The process by which a liquid is separated into its parts or by which some parts are separated from a liquid by passage of an electric current through a liquid.

ELECTROLYTE
A liquid which is separated into its different parts when an electric current passes through it, as in a storage battery.

ELECTROLYTIC RECTIFIER
An aluminum cell rectifier.

ELECTROMAGNET
A soft iron or soft steel magnet formed by the action of current passing through a coil around the magnet. It loses most of its magnetism as soon as the flow of current is stopped.

ELECTROMAGNETIC ATTRACTION
The attraction between opposite poles of electro-magnets.

ELECTROMAGNETIC FIELD
A magnetic field produced by electro-magnets.

ELECTROMAGNETIC INDUCTION
The production of electromotive force and currents in conductors by the movements of electromagnetic fields.

ELECTROMETALLURGY
Operations in which the electric current is used for the working of metals.

ELECTROMETER
An instrument for measuring very small potentials or voltage.

ELECTROMOTIVE FORCE
Electrical pressure or potential which tends to cause a flow of current in a circuit, altho the force may exist without a current if there is no circuit. Abbreviated E. M. F.

ELECTRON
A minute particle of electricity, negative in polarity.

ELECTRON THEORY
The theory that electrons form a part of the atoms in all forms of matter and all the elements; that every atom consists of a positive center around which rotate negative electrons that may be detached from the atom under certain conditions, leaving the atom positive.

ELECTROPLATING
The plating of metals by depositing them on one of the electrodes in an electrolytic cell.

ELECTROSCOPE
A device which shows the presence of very small amounts of electricity or potential.

ELECTROSE
A hard, moulded insulating material.

ELECTROSTATIC
Dealing with static electricity: Electricity at rest as in the electric charge of a body such as the plates of a condenser.

ELECTROSTATIC CAPACITY
The capacity of a condenser to hold an electric charge. Measured in farads or microfarads.

ELECTROSTATIC FIELD
The space in which electrostatic effects take place around a conductor carrying an electric charge.

ELECTROTHERAPY
Treatment of disease by means of electricity.

ELECTROTYPE
A printing plate made by depositing metal on a form by means of electric cur-

rent in an electrolytic cell.

E L E M E N T
One of the parts of which all matter is composed, a part which may be separated from the others.

E M P I R E   C L O T H
An insulating cotton or linen cloth coated with linseed oil.

E N A M E L E D   W I R E
Conductor wire insulated with flexible enamel which is baked on the wire.

E N C L O S E D   F U S E
A fuse enclosed in a glass or fibre tube to prevent contact of the arc with inflammable vapors.

E N D   P L A Y
The distance that a shaft or a part mounted on a shaft can move freely in a line with the shaft's length.

E N D   T H R U S T
The thrust that is exerted endwise or in line with a shaft.

E N E R G I Z E
To cause a magnetic material, such as a magnet core to become magnetized or magnetic. To send current through a circuit or through a winding or coil.

E N E R G Y
Capacity for performing work.

E N T R A N C E   S W I T C H
A switch connected in a circuit where the wires enter a building.

E R Y T H E M A
A superficial redness of the skin.

E T H E R
A light, volatile, colorless liquid with aromatic odor used as an anaesthetic by inhalation.

E X C I T E
To magnetize.

E X T E N S I O N
A flexible cable used to connect a lamp or other electrical device to a socket from which current is secured.

E X T E R N A L   C I R C U I T
All of the wires and conductors which are outside the source.

F .
An abbreviation for "frequency", cycles per second.

F A C T O R
Any value or condition that affects or changes a result.

F A H R E N H E I T
A thermometer scale having a freezing point at 32^{o} and a boiling at 212^{o}.

F A L L   O F   P O T E N T I A L
The drop of voltage between different points in an electric circuit.

F A L S E   R E S I S T A N C E
The resistance effect of counter electro-motive force.

F A R A D
The unit in which electrostatic capacity is measured. It is the capacity of a condenser which will give a pressure of one volt when a current of one ampere flows into it for one second. A condenser whose potential is one volt with a charge of one coulomb.

F A R A D I C   C U R R E N T
An intermittent current produced by induction.

F E E D E R
A conductor running from a source or main supply of current, to a central point at which current is divided for different circuits.

F E E D E R   P A N E L
A panel or unit of a switchboard at which connections are made to a feeder.

F I B R E
A hard tough material of rubber-like texture.

F I E L D
The space in which are the magnetic lines of force around the magnet. Sometimes applied to the magnet cores as well as the space around them.

F I E L D   C O I L
The winding or conductor around the field magnets of generators, motors, etc.

F I E L D   M A G N E T
The iron and steel parts through which the field lines of force pass in a generator or motor.

F I E L D   P O L E
One of the ends of the field magnet between which an armature of a generator or motor rotates.

F I L A M E N T
The fine thread-like conductor that carries current in an incandescent lamp and which becomes white hot to give light.

F I L A M E N T
The filaments in different x-ray tubes - even of the same type - do not necessarily have the same resistance. Therefore it is necessary to recalibrate each tube for specific pre-reading filament heats for the M. A. values to be used.

F I L A M E N T   C O N T R O L
A device for regulating the filament temperature.

F I L A M E N T   T R A N S F O R M E R
A step down transformer that supplies the current for the x-ray tube filament.

FILTER
A filter is any substance, oil, aluminum, copper, the composition window of oil immersed x-ray tube assemblies.

A filter absorbs some of the longer wave lengths.

Filtration, equivalent to that of ½ m. m. of aluminum is routinely used for radiographic work below 90 K. V. P.

FISH PAPER
A strong paper used for insulation.

FISH WIRE
A flat steel wire used for pulling conductors through conduits and raceways.

FIXED RESISTANCE
A resistance that is not adjustable.

FLEXIBLE CABLE
Cable made up of stranded or woven conductors.

FLEXIBLE CONDUIT
Conduit made of fabric and insulating compound.

FLUCTUATING CURRENT
A current whose voltage and amperage change at irregular intervals while always flowing in the same direction.

FLUORESCENCE
The property of certain substances to become luminous when exposed to x-ray.

FLUOROSCOPE
A device for visual x-ray examination.

FLUOROSCOPY
A visual x-ray examination.

FLUSH RECEPTACLE
An electric lamp socket which mounts against a flat surface.

FLUSH SWITCH
An electric switch which mounts against a flat surface.

FLUX
The magnetism or lines of force flowing through a magnetic circuit. Measured in maxwells.

FLUX DENSITY
The number of lines of force in a given cross sectional area.

FOCAL AREA
The area of electron bombardment on the face of the x-ray tube anode.

FOCAL SPOT (ACTUAL SIZE)
The size of the focal area when projected at 90° to the face of the anode.

FORCE
That which changes the speed or motion of anything, either to cause motion, to increase or decrease the speed, to stop motion.

FORM FACTOR
The ratio of the effective value of one-half a cycle of alternating current to its mean average length.

FREQUENCY
The number of cycles per second of an alternating current.

FREQUENCY CHANGER
A motor generator set driven by alternating current of one frequency and generating current of another frequency.

FREQUENCY CONVERTER
A converter which changes the frequency of alternating currents with or without a change in the voltage or the phase.

FRICTION TAPE
Tape filled with some adhesive compound. It is a good insulator for low voltages.

FULGURATION
"Destruction by flashing". This may be direct or indirect. Direct: An insulated fulguration electrode with a metal point is connected to the uniterminal of the high frequency apparatus and a spark of electricity is allowed to impinge on the area to be treated. This miniature arc may be long or short, cold or hot. In general, the shorter the arc the less the pain. Indirect method: In this procedure the patient is connected directly by means of a metal handle to the uniterminal and the operator draws, by means of a lead pencil, an arc from the patient. This is less painful and its action is more superficial.

FUSE
A conductor which will melt and break a circuit when more than a certain amount of current flows in the circuit containing the fuse.

a. A current limiting device.

FUSE BLOCK
A piece of insulating material designed to carry fuses and their connections.

FUSE BOX
A covered box in which fuse blocks and fuses are carried.

FUSE CLIP
A spring clip to hold the ends of a cartridge fuse.

FUSE LINK
An unenclosed fuse.

FUSE PANEL
A panel on which fuses and their connections are mounted.

FUSE PLUG
A fuse carried in a screw plug which can be inserted in a socket like a lamp.

FUSE STRIP
A fuse in the form of a thin flat strip rather than a wire.

FUSE WIRE
A fuse in wire form.

GALVANIC CURRENT
See Direct Current. This current was first produced chemically from batteries. At present its sources are:

1. A direct current lighting or power circuit ("Main").

2. Alternating current circuit with introduction of:

   (a) Motor generator.

   (b) Rectifier.

   (c) "B-Battery" eliminator.

3. Battery of cells, dry or wet.

It should be remembered that the galvanic and so-called static currents are the only unidirectional currents and the only ones possessing constant polarity.

GALVANOMETER
An instrument for measuring small currents or voltages.

GANG SWITCH
Two or more separate switches assembled in one holder as a unit.

GENERATOR
A machine which changes mechanical power into electrical power.

GENERATOR EFFICIENCY
The ratio of the power it takes to drive a generator to the electric power of the current generated.

GENERATOR LOSS
The loss of power between that required to drive a generator and the power generated. It is made up of both the electrical and mechanical losses.

GERMAN SILVER
A resistance alloy containing copper, nickel and zinc.

GOLD LEAF ELECTROSCOPE
An electroscope in which a small piece of gold leaf is moved by an electromotive force.

GRAPHITE
A form of carbon which is an excellent conductor.

GRID
An electrode or electric pole placed between the filament and the plate of an electron tube and controlling the current between the filament and the plate.

(Radiographic), a device constructed of alternately spaced opaque and translucent materials used to absorb secondary radiation.

GROUND
An electrical connection to the earth or to the metal framework or supports of electrical parts.

A wire connecting directly to the earth, usually through a gas, water, or steam line.

GROUNDED CIRCUIT
A circuit completed through ground, through the earth, or the metal parts of electrical parts.

GROUND INDICATOR
An instrument which indicates when an accidental ground connection exists in a circuit.

GROUNDED NEUTRAL
A grounded neutral wire in a three-wire circuit.

GUTTA-PERCHA
A material similar to rubber.

H. P.

An abbreviation for "horsepower".

HEAT LOSS
The loss of power due to increased resistance in heated conductors.

HELIX
A conductor formed into a coil, a solenoid.

HENRY
The unit for measuring inductance. A circuit has an inductance of one henry when a current which changes at the rate of one ampere in a second produces a pressure of one volt in the circuit.

HETEROGENEOUS
Differing in nature; unlike or dissimilar in kind.

HIGH-FREQUENCY
Alternating current or pulsating electric wave-frequencies running into thousands or millions per second.

HIGH-FREQUENCY COIL
An induction coil giving discharges at high frequency due to the oscillating discharge of the condenser.

HIGH-POTENTIAL
High voltage, usually above 1000 volts.

HIGH-RESISTANCE
A resistance considerably above the resistance that ordinarily exists in a circuit or part of a circuit.

HIGH-TENSION
High voltage, voltage of a thousand or more volts.

HOMOGENEOUS
Having the same nature; consisting of similar parts or elements of like nature.

HORSEPOWER
The unit in which mechanical or electrical power is measured. One horsepower is the power required to raise 33,000 pounds one foot in one minute.

HOT
A word used to mean that a conductor is carrying current.

HYDRAULIC
Pertaining to water or fluids in motion.

HYDROELECTRIC
Relating to the generation of electricity from water power or hydraulic power.

HYPEREMIA
Excessive amount of blood in any given part of the body.

HYSTERESIS
The opposition of soft iron or steel to a change, either increase or decrease, in its magnetism.

HYSTERESIS LOSS
The work or power required to reverse the direction of magnetism in iron or steel.

I
An abbreviation for "intensity" of current; amperes.

IMPEDANCE
The apparent resistance of an alternating current circuit; both the resistance and the reactance.

IMPEDANCE FACTOR
The ratio of the alternating current impedance in a circuit to the ohmic resistance in the same circuit.

IMPREGNATED CLOTH
Cloth which has been impregnated, not only coated, with varnish or oil to give it high electrical resistance.

IMPRESSED VOLTAGE
The voltage or pressure coming from an electric source and acting at the terminals of a circuit or electric device.

IMPULSE
One alternation of an alternating current. One half of a cycle.

INDUCED CURRENT
Current caused by mutual or electromagnetic induction.

INDUCED ELECTROMOTIVE FORCE
Voltage produced by mutual or electromagnetic induction.

INDUCED MAGNETISM
Magnetism produced from the action of electric currents or by the action of other magnets.

INDUCED VOLTAGE
Voltage produced by mutual or electromagnetic induction.

INDUCTANCE
The induction in a circuit or the ability of a circuit to produce induction in other circuits, respectively called self-induction and mutual inductance. Measured in henrys.

INDUCTION
The action by which an electromotive force is induced in a conductor or magnetism in a magnet by nearby bodies, either conductors or magnets, around which there is a magnetic field.

INDUCTION COIL
A coil having an iron core and two windings, in one winding of which a high voltage current is induced by changes of current strength in the other winding, the changes causing an increase and decrease of magnetic field from the core.

INDUCTION LOAD
In alternating current work, a load whose current lags in phase behind the voltage across the load.

INDUCTIVITY
The ability or capacity of a circuit or coil for induction.

INDUCTOR
In an electric machine, a rotating iron or steel part which causes changes in the direction or value of magnetic flux or lines of force.

INPUT
The power required to operate any electrical device, all of the power consumed in such a device.

INSULATE
To place a non-conductor or insulator around a conductor to prevent current from leaving the conductor at its insulated parts.

INSULATOR
Any material in which the electrons - or current - does not flow easily.

An extremely poor current carrier.

The higher the resistance the better the insulator.

INTERMITTENT CURRENT
A current that starts and stops at regular intervals.

INVERSE
That current which may be forced into a tube in the wrong direction.

Excessive Inverse may puncture a tube (x-ray or valve).

INVERSE RATIO
An increase of one value with a decrease of another.

ION
One of the electrified particles consisting of an atom or group of atoms into which the molecules of an electrolyte are divided; or one of the electrified particles into which the molecules of a gas are divided by ultraviolet rays, gamma rays or x-rays, or by other ionizing agents.

IONIC MEDICATION
The introduction of chemical ions into the superficial tissues for medicinal purposes by means of a direct current. The basic rules are: Like forms of electricity repel each other; unlike forms attract each other. Bases, metals and alkaloids are electropositive and hence should be placed at the positive pole. Acids and acid radicals are electro-negative and hence should be placed at the negative pole. Examples of this: Potassium iodide for the introduction of free iodine should be placed at the negative pole, cocaine hydrochloride for local anesthesia at the positive pole.

IONIZATION
Separation of portions of an electrolyte into its chemical elements by electrolysis.

IRON LOSS
The loss of power due to hysteresis and to eddy currents in the iron cores of electric machines.

JOINT
A permanent soldered connection or semi-permanent screwed or clamped connection in an electric circuit.

JOULE
A unit for measuring electric work. It is the work done by a current of one ampere flowing through a resistance of one ohm for one second.

JUMPER
A conductor connected around a part of a circuit, the connection being made for emergency work or test purposes.

JUNCTION BOX
A box in which branch circuits are connected to mains.

K V
An abbreviation for kilovolt.

K V A
An abbreviation for kilovolt amperes.

K V E
An abbreviation for kilovolt effective.

K V P
An abbreviation for kilovolt peak.

K. W.
An abbreviation for kilowatt.

KWH
An abbreviation for kilowatt hour.

KAOLIN
A kind of porcelain or china used for insulators.

KEEPER OF MAGNET
A piece of iron placed across the poles of a magnet while the magnet is not being used.

KILO
Prefix meaning 1000.

KILOAMPERE
One thousand amperes.

KILOVOLT
One thousand volts.

KILOWATT
One thousand watts.

KNIFE SWITCH
A switch consisting of a thin blade which passes between two flat surfaces or shorter blades to complete a circuit.

LAG
Coming after something else that is related; as the magnetic lag (hysteresis) lag of a phase, etc.

LAG OF PHASE
An alternating current whose maximum value comes after the maximum of a second alternating current of the same frequency is said to lag in phase with reference to the first current.

LAMINATED CORE
A magnetic core made up of thin sheets of soft iron or steel laid side by side. This construction reduces the eddy current.

LEAD
Short lengths of wire through which current is carried to and from an electrical device.

LEAD OF PHASE
An alternating current whose maximum value comes before the maximum of a second alternating current of the same frequency is said to lead the second current in phase.

LEAD IN WIRES
The wires through which a circuit is brought into a building.

LEAK
A loss of current through a short circuit or an accidental ground.

LINE DROP
The drop of voltage in the conductors of a power or lighting circuit.

Drop in primary or line voltage.

Influenced by small line wire, too small line transformer, overloaded line, lack of generator capacity.

Determine line drop by connecting voltmeter across line. Take a reading load off and one with load on. The difference in voltage reading represents the line drop.

LINE INSULATOR
An insulator used to carry an overhead wire.

LINE OF FORCE
An imaginary line which indicates the direction in which magnetism flows between magnetic poles or around conductors carrying a current or an electric charge. A unit in which magnetic flux is measured.

LINE REACTANCE
The reactance in the lines outside of a power station, between the station and the points at which power is used.

LINE RESISTANCE
The resistance in the line outside of a power station.

LINK FUSE
An unenclosed fuse.

LIVE
(See hot).

LOAD
Power required to operate current consuming devices.

LOAD FACTOR
The ratio of the average power consumed to the maximum power, in any given time.

LOAD TEST
A test of an electrical device operating with its normal load.

LOAD VOLTAGE
Voltage measured when an electrical device is operating.

LOW FREQUENCY
An alternating or pulsating current having a small number of cycles or impulses per second. Usually less than two hundred of either.

LOW POTENTIAL SYSTEM
A low voltage system, usually one operating at less than 600 volts.

LOW TENSION
Low Voltage.

LOW TENSION WINDING
In a transformer or induction coil, the primary winding which carries the lower voltage.

LUGS
Terminals placed on the end of conductors.

LUMEN
The light of one standard candle passing through a square centimeter of space one centimeter from the source of illumination.

LUMINOSITY
In illumination, the brightness of a color when compared with white.

LUMINOUS FLUX
In illumination, the radiation with reference to visibility or the sense of light, measured in Lumens.

M.
A symbol for henrys, measuring mutual induction.

M. A.
An abbreviation for Milliampere.

M. A. S.
An abbreviation for milliampere second.

M. F. D.
An abbreviation for micro-farad.

MAGNET
A body which will attract magnetic materials, iron, and steel.

MAGNETIC BLOW-OUT
A magnet which reduces the arcing at current breaking contacts due to the effect of the magnetism on the arc.

MAGNETIC BRAKE
A brake operated by electromagnets but using friction for retarding the motion of the parts.

MAGNETIC CONTACTOR
A device operated by an electro-magnet to close and open contacts in a circuit.

MAGNETIC FIELD
The space around a magnet.

MAGNETISM
Ability of an energized coil or a natural magnet to attract particles of steel, iron, or nickel.

MEGOHM
Resistance of one million ohms.

METABOLISM
Tissue change; the sum of all the physical and chemical processes by which

living organized substance is produced and maintained. Also the transformation by which energy is made available for the uses of the organism.

M E T E R
A standardized device for measuring.

M I C A
An insulating material.

M I C R O B E
A single celled microscopic plant; a bacterium.

M I C R O F A R A D
One millionth of a farad.

M I L
One one-thousandth of an inch.

M I L L I A M M E T E R
See Ammeter.

M I L L I A M P E R E
One one-thousandth of an ampere.

M I L L I M I C R O N
One one-thousandth part of a micron, a millionth part of a millimeter.

M I L L I V O L T
One one-thousandth of a volt.

M O L E C U L E
A chemical combination of two or more atoms which form a specific chemical substance; the chemical elements are formed by the combination of like atoms. Combinations of dissimilar atoms form chemical compounds. In normal molecules the positive and negative electric charges exactly balance. Excess or deficiency of either positive or negative charge by the loss or acquisition of negative electrons results in the formation of an ion.

M O N O C H R O M A T I C
Having but one color.

M O N O T E R M I N A L
Use of one terminal only in the giving of treatments, the ground acting as the second terminal for the completion of the electrical circuit.

M O T O R   G E N E R A T O R
A transforming device consisting of a motor mechanically connected to a generator. Such machines are designed to generate direct current when alternating alone is available or vice versa.

N I C H R O M E
An alloy of nickel and chromium.

N O N C O N D U C T O R
A substance that will not conduct electricity. Strictly speaking, there is no perfect nonconductor. On the application of a sufficiently high voltage,

current may be caused to flow through materials usually spoken of as nonconductors. (See insulator.)

NON-ELECTROLYTE
A solution that is a nonconductor.

NON-PATHOGENIC
That which does not cause disease.

OHM
The unit of measurement of resistance to flow of current. One ohm is the resistance that allows one volt pressure to send one ampere of current flow through a circuit.

OHM'S LAW
The rule or law giving the relations of the pressure in volts, the current in amperes, and the resistance in ohms for an electric circuit. Amperes are equal to volts divided by ohms; volts are equal to amperes multiplied by ohms; ohms are equal to volts divided by amperes.

OHMMETER
An instrument which measures and directly indicates resistance in ohms.

OHMIC RESISTANCE
The resistance that is due only to a conductor's material, size, length and temperature. It is the resistance to flow of direct current. The resistance to alternating current is higher because of the opposing currents produced by the alternations.

OIL
In an x-ray transformer oil is used for insulation. The oil must be kept at the proper level.

Transformer Oil is a special high grade dehydrated oil.

In the absence of special transformer oil, a good grade of light mineral oil can be used.

OIL CIRCUIT BREAKER
A high voltage circuit breaker whose contacts open in a bath of oil which puts out the arc.

OILED CLOTH
Cotton or muslin cloth treated with linseed oil to increase its insulating strength.

OILED MUSLIN
Cotton cloth filled with insulating varnish.

OILED PAPER
Paper treated with linseed oil or varnish to make it a good insulator.

OIL SWITCH
A switch whose contacts break in an oil bath.

OIL TRANSFORMER
A transformer which is insulated by a bath of oil. The oil circulates and

cools the heated parts of the transformer while acting as an insulator.

OKONITE
A special rubber insulation used on wires.

ONE-WIRE
Pertaining to parts and connections used in circuits having one side grounded, requiring but one separate contact in the devices.

OPEN CIRCUIT
An incomplete circuit, one broken at any point, so that current does not flow through any part of it.

OPEN-CIRCUIT BATTERY
A primary electric cell suitable for use only on circuits which are open most of the time, which operate only for short intervals.

OPEN-COIL ARMATURE
An armature in which the ends of one coil are not connected to the ends of other coils at the commutator segments and are therefore open circuited except when connected to the brushes.

OPEN DELTA CONNECTION
A connection of two transformers so that they form only two sides of a "delta" or triangular connection, in place of the three sides with three transformers in a regular delta connection.

OPEN LINK FUSE
A fuse that is not enclosed in a tube of fibre or glass.

OPEN MACHINE
An electric machine whose housing or framework is open for ventilation.

OPEN-CIRCUIT VOLTMETER
A voltmeter which measures voltage without allowing any current to flow through it. It operates by the electrostatic charges produced.

OPEN WIRING
Wiring that is not carried in conduit or moulding.

OPPOSITE PHASE
A current in which the maximum points of its waves come exactly opposite each other, 180 degrees apart. (See phase.)

ORDINATE
The vertical distance of a point on a curve above or below the horizontal base line for the curve. The ordinate is a line drawn from the base vertically to the point to be specified.

OSCILLATING CURRENT
A current alternating in direction, and of either constant or gradually decreasing amplitude. An oscillating current of constant amplitude is called an undamped current; one of gradually decreasing amplitude, a damped current.

OSCILLATING DISCHARGE
A series of discharges from a condenser.

OSCILLATION
A movement of electricity in a high-frequency circuit or a movement of an electric wave in the air.

OSCILLOGRAPH
A galvanometer which measures and indicates alternating current waves.

OSCILLOSCOPE
A sensitive galvanometer used to indicate the successive instantaneous values of a rapidly changing current.

This instrument is used to study the characteristics of a variable current such as an alternating current.

OUTLET
A place at which electric wires in buildings are exposed for the attachment of various devices to be connected to the circuits.

OUTLET BOX
A box at which the concealed wiring in a building is exposed for attachment of devices and fixtures.

OUTPUT
The amperes or the watts delivered by a generator or a battery.

OUTPUT CONTROL
Controlling the amperage or voltage of a generator.

OVERFILLING OF BATTERY
Adding water to storage battery cells to bring the electrolyte high enough so it overflows.

OVERHEAD LINE
The wiring which is carried on elevated poles, as distinguished from underground wiring.

OVERLOAD
A load in amperes greater than an electric device or circuit is designed to carry or to operate with.

OVERLOAD CIRCUIT BREAKER OR SWITCH
A circuit breaker arranged to open when the current exceeds a certain value for which the breaker is set.

OVERVOLTAGE
The additional voltage required for electrolysis with some metals as electrodes above the voltage required with other metals.

OZOKERITE
An insulating wax.

OZONE
A form of oxygen produced by electric discharges or sparks passing through air.

P.
An abbreviation for "power", watts.

P . D .
An abbreviation for "potential difference".

PANEL CUTOUT
A fuse cutout for mounting in a panel box.

PAPER CONDENSER
A condenser using paper for dielectric.

PARABOLIC REFLECTOR
A form of curved reflector, which, with the light at a position called the focus, sends all the reflected rays straight in one direction.

PARAFFIN
A wax-like material used for insulating purposes.

PARAFFINED PAPER
Paper treated with paraffin to improve its insulating properties.

PARALLAX
In reading an instrument having a pointer, the difference between the pointer's apparent position on the scale when looked at from an angle, and the true position when looked at from straight in front of the pointer.

PARALLEL CIRCUIT OR CONNECTION
Several circuits or electrical parts so connected that current from a source divides between them, or so that current from them flows into a single path. A multiple connection or shunt connection.

PARALLEL-SERIES
Another name for multiple series.

PARAMAGNETIC
Materials which are attracted by a magnet. Iron, steel, nickel and cobalt are paramagnetic.

PASTE JOINT
The joint around the leading-in wires of a lamp bulb.

PATHOGENIC
Disease producing.

PEAK FACTOR
The ratio of the maximum value of an alternating current to its effective value.

PEAK LOAD
The greatest load on an electrical system or circuit in a certain period of time.

PEAK POWER
The average power during a period when the power is at a maximum.

PEAK VOLTAGE
The highest voltage attained in a circuit in a given period.

PERIOD OF CURRENT
The time during which an alternating current passes through one complete cycle or positive and negative wave.

PERIOD OF INSTRUMENT
The time it takes the pointer of an instrument to make a swing from zero, one way, then the other, and back to zero.

PERIODIC CURRENT
An alternating current or a pulsating current.

PERIODICITY
The rate of rise and fall or interruption of a unidirectional current.

PERMANENT MAGNET
A hard steel magnet which keeps its magnetic strength for long periods of time with little change.

PERMEABILITY
The ability of a certain magnetic material to carry magnetic flux or lines of force, a measure of the ease with which the flux is carried. Opposed to reluctivity.

PERMEABILITY CURVE
A curve showing the relation between the magnetizing force in ampere-turns and the magnetic flux produced in a given magnetic material.

PERMEAMETER
An instrument which tests the permeability of iron and steel.

PERMEANCE
The ability of a material to carry magnetic flux or lines of force. The opposite of reluctance.

PERMITTANCE
The electrostatic capacity of a condenser.

PERMITTIVITY
The dielectric constant, the permittance through a centimeter cube of a dielectric. This is an electrostatic unit similiar to conductivity in speaking of electric currents.

PHASE
The point or position to which an alternating current wave has increased toward maximum from the position of zero potential. It is a part of an alternating current cycle measured from the zero point. It is measured in degrees, one complete cycle being divided into 360 degrees. To be "in phase" means that the maximum points of two waves come at the same instant. "Out of phase" means that the maximum points do not come together.

PHASE ADVANCER
An electric machine used in connection with induction motors, but whose current is not in phase with the motor. The motor's pulling power is improved by the effect of the phase advancer.

PHASE ANGLE
The difference between the maximum points of two alternating current waves,

measured in degrees. (See phase.)

PHASE DETECTOR
An instrument which indicates when two alternators are in step or synchronized.

PHASE DIFFERENCE OR DISPLACEMENT
The difference between corresponding points on the waves of two alternating currents having the same frequency. It is measured in degrees of the cycle expressed as angles.

PHASE METER
An instrument for indicating the phase difference between two alternating currents.

PHASE MODIFIER
A device which corrects the lag of alternating currents.

PHASE SPLITTER
A device which divides a single phase current into parts from which an induction motor can start itself. Also, a device for dividing a multiphase current into currents of different phases for different circuits.

PHOTOMETER
An instrument which measures the amount of light from a source or which compares the light from different sources.

PHYSICAL THERAPY
Physical Therapy is the therapeutic use of physical agents. It comprises the use of physical, chemical and other properties of heat, light, water, electricity, massage and exercise.

PILOT LAMP
A small electric lamp connected to a circuit so that lighting or extinguishing of the light indicates the flow of current in the circuit and whether other electrical devices or lamps are operating.

PLATE CONDENSER
A condenser formed of plate conductors with the dielectric between them.

PLATINUM
A silver-white, non-corrosive metal having a very high melting point and much used for making contact points which separate to break a circuit.

PLATINUM-IRIDIUM ALLOY
Platinum to which iridium has been added to increase the hardness of the resulting alloy.

PLUG
A word applied to parts which make an electric connection between a threaded socket and threaded plug that screws into a socket.

PLUG SWITCH
A switch that completes a connection between a socket attached to one side of the circuit and a metal plug that pushes into the socket.

PLUNGER MAGNET
An electromagnet whose core forms a plunger which may be moved out of the

winding and is then drawn back into it by the action of the magnet.

POLARITY
Being positive or negative in magnetism, or in the direction of current flow and potential.

POLARITY CHANGER
Any device which changes the direction of the polarity in a circuit or changes the polarity from the terminals of a source.

POLARITY INDICATOR
An instrument which indicates the positive and negative ends of a circuit. Some devices use a voltmeter movement, others use chemicals in liquids which change color.

POLARIZATION
The formation of gases on the plate surfaces in electric batteries. The gases are formed from the electrolyte by the electrolytic action and form a partial insulator on the plates.

POLARIZED
Having a definite magnetic polarity, positive or negative.

POLARIZED RELAY
A relay using a polarized armature.

POLE
In magnetic parts, the magnetic pole. In electric currents, the positive or negative terminal.

POLE ARMATURE
An armature whose coils are placed on pole pieces standing out from a center, or arranged around the inside of a circle and pointing toward the center.

POLE CHANGER
A device which acts to rapidly change the polarity or direction of current flow through a circuit so that the current may be used to operate signalling devices.

POLE PIECE
On a field magnet or an electromagnet, the end that forms one of the magnetic poles. The separate piece attached to field structures for the purpose of forming magnetic poles.

POLYPHASE
A word applied to alternating current circuits meaning that they carry two or more voltages having the same number of cycles but not in phase with one another.

POLYPHASE ALTERNATOR
An alternating current generator producing currents of more than a single phase.

POLYPHASE CIRCUIT
Alternating current circuits carrying more than a single phase of current.

POLYPHASE CURRENT
A current in which there are two or more different phases.

POLYPHASE GENERATOR
A polyphase alternator.

POLYPHASE MOTOR
An alternating current motor operating on two or more phases of current or through a phase converter from a single-phase supply.

POLYPHASE SYSTEM
All the circuits connected to a polyphase alternator and in which are currents of different phases.

POLYPHASE TRANSFORMER
A transformer used in a polyphase system.

PORCELAIN
An insulating material made from clays and sand, moulded and baked. It has high resistance and withstands heat quite well.

PORTABLE INSTRUMENT
Any electrical instrument mounted in a case so that it may be carried from place to place and with terminals to which temporary testing connections may be made.

POSITIVE
In a circuit, those parts away from which the current flows, the parts having a higher electrical pressure than other parts. In a magnet or magnetic circuit, the parts away from which the lines of force travel or from which they come out. Opposite to negative.

POSITIVE BRUSH
A generator brush through which current leaves the armature. A motor brush through which current enters the armature. Any brush connected in the positive side of a circuit.

POSITIVE CHARGE
A charge of electricity of positive polarity. The charge on a condenser plate connected to the positive side of a source.

POSITIVE CONDUCTOR
A conductor attached between the positive side of an electrical source and the positive side of a current consuming device.

POSITIVE ELECTRICITY
Electricity at higher pressure or potential than the pressure in another part of a circuit.

POSITIVE ELECTRODE
An electrode through which current leaves the electrolyte.

POSITIVE ELEMENT
In a battery or cell; the assembly of plates from which current leaves the battery or cell. It is properly called the positive group.

POSITIVE PLATE
In a battery or cell; the plate from which current leaves the battery or cell. In a lead-acid battery, the peroxide of lead plate.

POSITIVE POLE
In a magnet; the pole at which the lines of force leave the magnet. The north pointing pole of a compass needle.

POSITIVE POTENTIAL
The higher pressure or voltage. Points in an external circuit away from which current is flowing are said to have positive potential with reference to parts toward which the current flows.

POSITIVE SIDE
The parts in a circuit between the point from which current leaves the source and the point at which the current enters the current consuming device.

POSITIVE SIGN
The plus sign (+). It stands for a positive conductor or the positive pole of a magnet.

POSITIVE TERMINAL
The terminal on a source from which current leaves the source. The terminal on a current consuming device which is connected with the positive of the source. The end of a conductor at which current leaves the conductor.

POTENTIAL
Electromotive force, pressure, or voltage.

POTENTIAL DIFFERENCE
The difference in electrical pressure or voltage between two points in a circuit. The potential difference causes a flow of current.

POTENTIAL GRADIENT
The rate at which the voltage or potential changes along a circuit, the potential difference measured over certain distances.

POTENTIAL REGULATOR
A transformer in which the amount of induction may be adjusted to control the voltage.

POTENTIOMETER
An instrument for making active comparisons between a known voltage or standard voltage, and another voltage.

POWER
The rate at which work is done; measured in such units as the horsepower, the foot-pound-second, etc.

POWER OF ALTERNATING CURRENT
The average value of the power in watts through a complete cycle.

POWER CIRCUIT
A circuit supplying current to electric motors or other devices using electric power for industrial work.

POWER FACTOR
The ratio of the actual power of an alternating current to its apparent power.

POWER FACTOR METER
A form of watt-meter which directly indicates the power factor of a circuit.

POWER LOSS
The power, measured in watts, that disappears in transmitting current through a circuit.

POWER TRANSFORMER
A transformer used for handling current of large power.

PRACTICAL UNIT
Units of electrical measurement that are generally employed in practical work. They include the volt, ampere, ohm, coulomb, joule, watt, farad, and henry.

PRECISION INSTRUMENT
An electric measuring instrument, ammeter, voltmeter, wattmeter, etc., in which the variation from the actual values is very small.

PRESSURE
The force being exerted. It does not necessarily cause motion or do work. Electric force is measured in volts. It is the electromotive force or potential.

PRIMARY
The part of any electrical device, or the circuit, attached directly to the source, as distinguished from secondary which means parts depending on the primary in place of directly on the source. Also, a source that produces electricity for something else; as mechanical or chemical action.

PRIMARY CIRCUIT
A circuit connected directly to a source.

PRIMARY COIL
See primary winding.

PRIMARY CURRENT
The current which flows from the source in a primary circuit.

PRIMARY WINDING
In an electrical device, the winding which receives current from the outside circuit.

PRIMARY WIRE
In ignition work, wire having a large conduction with comparatively little insulation, suitable for use with low voltage primary current.

PROPORTIONAL
A change of one value in accordance with change in another value.

PROTON
The nucleus of the hydrogen atom. It is assumed to be the unit positive charge of electricity. (See electron.)

PULSATING CURRENT
An electric current which rises and falls in value. It is usually an intermittent direct current.

PUNCTURE
Breaking through an insulator by a high-voltage current.

PUNCTURE TEST
Testing insulation by gradually raising the voltage difference between ends of conductors on opposite sides of the insulation or connected to other conductors between which the insulation lies.

PUSH-AND-PULL SWITCH
A switch to which is connected a small button which is moved in and out to open or close the switch.

PUSH BUTTON
A form of switch which is closed by pushing on a button and is opened by a spring.

Q.
An abbreviation for "quantity" of electricity, coulombs or ampere-hours.

QUANTITY
Electrical quantity is the amount of current passing through a circuit in a given time, or the amount of electric charge in conductors. It is measured in coulombs or in ampere-hours, ampere-minutes, etc.

QUARTZ BURNER
Element for the production of ultra violet.

R.
An abbreviation for "resistance", ohms.

R. P. M.
An abbreviation for "revolutions per minute".

RACING OF GENERATOR
Excessive speed of a generator caused by a quick drop in load.

RADIANT ENERGY
That form of energy which is transmitted through space without the support of an apparent medium. Radio waves, infra-red rays, visible rays, ultraviolet rays, x-rays, gamma rays, and the recently discovered cosmic rays are energy in this form.

RADIANT FLUX
In illumination, the radiation with reference to the electrical energy or power.

RADIATION
Giving off wave lengths.

RADIOACTIVE MATERIAL
Any substance which gives off positively or negatively charged particles, as radium.

RADIOMETER
An instrument which indicates the presence of rays of light or of heat by, their causing rotation of small vanes in a vacuum bulb.

RANGE OF INSTRUMENT
The smallest and greatest value that an electrical measuring instrument will measure or indicate.

RATED CANDLEPOWER
The candlepower that a lamp should give with a current of a certain voltage and amperage flowing through it.

RATING
The operating limit in amperage, voltage, power, heat, etc., of an electrical device. The word rating is often used in the sense of capacity.

RATIO
The relation of one number of value to another, such that a change of one necessitates a change of the other in order to preserve the same ratio. The ratio of 2 to 4 is the same as the ratio of 3 to 6, the ratio being 1 to 2 in both cases. Ratios can be written as fractions, all three of the above ratios, 2/4, 3/6 and 1/2 having the same value.

RATIO OF TRANSFORMER
The ratio of the number of turns in the primary winding of a transformer to the number of turns in the secondary winding.

REACTANCE
The resistance of a coil or condenser to an alternating current.

REACTANCE COIL, REACTIVE COIL, OR REACTION COIL
A choke coil.

REACTANCE FACTOR
The ratio of the resistance of alternating current to the ohmic resistance of a conductor.

REACTION KEY
A key which opens and closes a circuit with a very slight movement.

REACTIVE COMPONENT OR CURRENT
The part of a current that does no useful work, because its current phase is one quarter of a cycle different from the voltage.

REACTIVE FACTOR
In an alternating current, the ratio of the reactive component to the total volt-amperes.

REACTIVE LOAD
In alternating current work a load whose current is not in phase with the voltage across the load.

REACTOR
A device using reactance for the purpose of controlling or protecting electrical parts.

R E C E I V E R
The part of an electrical apparatus which changes the current impulses into sound through use of a diaphragm.

R E C E P T A C L E
A socket into which a plug is inserted to complete a connection in a circuit.

R E C I P R O C A L
The number 1 divided by the number or value of which the reciprocal is to be found. The reciprocal of 4 is 1/4.

R E C O R D I N G I N S T R U M E N T
An electric measuring instrument which makes a record of the values it measures.

R E C T I F I C A T I O N
The changing of an alternating current to a direct or a unidirectional current.

R E C T I F I E R
A device which changes alternating current into direct current by mechanical, electronic, or chemical action.

R E C T I F I E D
Direct current which has been produced from alternating current by a rectifier.

R E C T I F I E R E F F I C I E N C Y
The ratio of the power of the direct current delivered by a rectifier to the power of the alternating current going into the rectifier.

R E D L E A D
Peroxide of lead, used in storage battery plates.

R E G U L A T I O N
The change of some value that takes place in the operation of an electric device, the change or variation in voltage, current, speed, etc.

R E G U L A T I N G R E S I S T A N C E
Resistance that may be inserted in the field circuit or the main circuit of a generator for the purpose of regulating the generator's output.

R E G U L A T O R
A device for controlling the amperage or voltage, or both amperage and voltage, from a generator or in any circuit.

R E L A T I V E P E R M E A B I L I T Y
The ratio of the magnetic permeability of one material to another, or the ratio of permeability under different conditions in the same material.

R E L A Y
A device controlling a circuit by the opening and closing of its contacts when operated by current in the same or another circuit.

RELAY MAGNET
A telegraph instrument which operates the circuit in a local office by the effect of the incoming current on the relay.

RELAY REGULATOR
In automobile battery charging systems, the combination of a reverse current cutout and a regulator in a device using a single magnet for both actions.

RELUCTANCE
Resistance to flow of magnetism. Measured in oersteds.

RELUCTIVITY
The reluctance of one centimeter cube of a magnetic material, the specific reluctance.

REMAGNETIZER
A powerful direct current electromagnet used for magnetizing permanent magnets or magnetos.

REMOTE CONTROL
Control of electric motors or other devices through switches operated by electromagnets whose circuit is completed from a switch at some distant point.

RENEWABLE FUSE
A plug fuse or cartridge fuse in which the burned out fuse may be replaced with a new element.

REPEATER
A device which reproduces the signals from one telegraph circuit in another telegraph circuit.

REPEATING COIL
In telephone work, a transformer of one-to-one ratio.

REPULSION OF MAGNETS
The effect by which two magnet poles of the same polarity repel each other.

REPULSION INDUCTION MOTOR
An alternating current motor using induction for power and repulsion for starting or using both induction and repulsion effects.

RESIDUAL CHARGE
The additional discharge that may be secured from an apparently discharged storage battery after it has had a period of idleness without discharge.

RESIDUAL DISCHARGE
A discharge from a condenser after the first or initial discharge has been allowed to escape.

RESIDUAL MAGNETISM
The magnetism that remains in a piece of iron or steel when the magnetizing force is removed; as after the current stops flowing through the winding of an electromagnet.

RESISTANCE
An opposition to the flow of current. Measured in ohms.

RESISTANCE ALLOYS
Various metals made by melting two or more metals together into an alloy having high resistance and suitable for use in resistance units or heating units.

RESISTANCE BALANCE OR BRIDGE
A Wheatsone bridge.

RESISTANCE COIL
A coil of high resistance wire which may be inserted in a circuit to reduce the current flow.

RESISTANCE DIMMING
Lessening the amount of light from electric lamps by inserting resistance in their circuit.

RESISTANCE DROP
The voltabe drop caused by the resistance in a circuit.

RESISTANCE LOSS
The power in watts lost due to the resistance in a circuit or in an electric device.

RESISTANCE WIRE
Wire having high electrical resistance and at the same time able to withstand repeated heating and cooling.

RESISTIVITY
The resistance in ohms through a centimeter cube of the material, the specific resistance. Measured in ohm-centimeters.

RESISTER
The resistance employed in the control or operation of electrical device for their protection.

RESONANCE
Causing voltage impulses or waves in a conductor of certain length and capacity by similar impulses in a nearby conductor.

RESONATOR
An electrical circuit in which oscillations of a certain frequency are set up by oscillations of the same frequency in another circuit. When this occurs, the circuits are said to be in syntony.

RETARDATION COIL
A choke coil used in telephone circuits for lessening interference between different circuits.

RETARDING DISC
The copper or aluminum disc in wattmeters. It is mounted between the poles of a magnet in order to slow down the rotation of the motor armature in the meter.

RETENTIVITY
The ability of a magnetic material to resist loss of its magnetism, to retain some lines of force even with the magnetizing effect removed.

RETURN CIRCUIT
The part of a circuit through which current returns from a current consuming device to the source.

REVERSE CURRENT CIRCUIT BREAKER
A circuit breaker which opens a circuit when the current starts flowing in an opposite direction.

REVERSE CURRENT CUTOUT
In automobile, battery charging systems, an automatic switch that opens the circuit between battery and generator when the generator's voltage is below the voltage necessary to charge the battery. In automatic cutouts, operated by an electromagnet, a small flow of reverse current is required to open their contacts.

RHEOSTAT
A resistance, the amount of which may be adjusted in a circuit.

RHEOSTAT REGULATION
Control of a generator's output or a motor's speed by an adjustable rheostat connected in their field circuit or their armature circuit.

RIGHT HANDED ROTATION
Rotation toward the right, in the same direction that the hands of a clock rotate.

ROENTGEN RAYS
X-Rays.

ROLLER CONTACT
An electrical contact between moving parts which is made through a small roller connected to one part and resting on the surface of the other part.

ROTARY CONVERTER
A device that changes Direct Current to Alternating Current.

S.A.E.
An abbreviation for "Society of Automotive Engineers".

S.A.E. SPARK PLUG
A spark plug whose shell has a straight thread 7/8 of an inch in diameter with 18 threads to the inch. Also called a 7/8 - 18 spark plug.

S. C.
An abbreviation for "single contact".

S.C.C.
An abbreviation for "single cotton covered" wire.

S.C.E.
An abbreviation for "single cotton covered enameled" wire.

S.S.C.
An abbreviation for "single silk covered" wire.

S. P.
Shockproof.

S. P.
An abbreviation for "single-pole".

SAFETY FUSE
The usual form of fuse which breaks a circuit when there is excessive current.

SAFETY GAP
Two electrodes connected to the positive and negative sides of a circuit, between which a spark can pass when the voltage becomes high enough to damage other parts in the circuit.

SAFETY SWITCH
A knife switch enclosed in a metal box operated from the outside by a handle.

SAL AMMONIAC BATTERY
A primary electric cell using sal ammoniac in solution for its electrolyte.

SALIENT POLE
A magnetic pole at the end of the iron part of a magnet. See also consequent pole.

SALINE SOLUTION
Salt solution.

SATURATION
The greatest number of lines of force or flux that a certain magnet or magnetic material will carry.

SATURATION FACTOR
The ratio of increase in field strength to the increase of voltage which results from it.

SCALING COMPOUND
An insulating compound which is poured around battery cell covers while hot and which makes a tight seal for the cells when it cools and hardens.

SECONDARY CURRENT
That current produced by the secondary windings of an induction coil or a transformer.

SECONDARY RADIATION
That radiation emitted by any substance through which x-rays are passing.

SECONDARY WINDING
That portion of a transformer in which current is induced.

SEDIMENT
A material which sheds from the plates and collects in the bottom of a storage battery jar.

SEGMENT
One of several contact pieces over which a contact point or brush is moved. A commutator bar.

SELECTIVE SIGNALLING
Any method of calling one subscriber on a party telephone line without calling the others on that same line.

SELECTOR SWITCH
A telephone exchange switch which connects automatically to a certain trunk.

SELENIUM
A substance whose electrical resistance becomes less when it is exposed to light.

SELENIUM CELL
A quantity of selenium between two metal conductors so that the change of resistance in the selenium affects the circuit resistance.

SELF-CLEANING CONTACT
A contact which, in closing or opening, has a slight wiping motion which assists in keeping it free from dirt or roughness.

SELF-EXCITED
An electric machine in which the field current is secured from its own armature current.

SELF-INDUCED CURRENT
The current produced in a conductor by self-induction.

SELF-INDUCTANCE
The ability of a circuit, or coil to produce induction in itself. See inductance.

SELF-INDUCTION
An opposing current or voltage induced in a circuit or coil by changes of current strength in itself.

SELF-RECTIFICATION
The ability of an electrical device to suppress negative half of each cycle.

SEPARABLE SPARK PLUG
A spark plug from which the insulator and center electrode may be removed when a packing nut is removed. A two-piece spark plug.

SEPARATELY EXCITED
Use of an exciter for sending current through the field windings of an electric machine in place of taking the field current from its own armature current.

SEPARATOR
A sheet of wood, rubber or other insulating material placed between the plates of storage battery cells to prevent electrical contact between the plates. The separators are porous or are perforated to allow passage of electrolyte through them.

SEPTIC
Productive of rotting or decay; opposite of aseptic.

SERIES CIRCUIT
A circuit in which all the parts are connected end to end so that all the current passing through any one part must also go through every other part in the circuit.

SERIES COIL
In a field winding, a relay winding, or similar electromagnetic part, the coil or winding through which all of the current in the main circuit flows.

SERIES CONDUCTOR
A conductor connected in series with other parts of the circuit.

SERIES CONNECTION
When two or more electrical devices or resistances are so connected that the current flows through them in succession, they are said to be connected in series.

SERIES FIELD
A field winding connected in series with the armature circuit.

SERIES GENERATOR
A generator whose field winding is connected in series with its armature circuit.

SERIES MOTOR
A motor whose field winding is connected in series with its armature circuit.

SERIES-MULTIPLE
Two or more multiple or parallel circuits connected in series with each other.

SERIES-PARALLEL DIMMING
A connection of two or more lamps so that they may be connected in parallel with each other for full brightness and in series with each other for dimming.

SERIES TRANSFORMER
A transformer connected in series with a circuit for the purpose of taking off a secondary power circuit.

SERIES TURN
The part of a field winding or an electromagnet winding that is connected in series with the armature or the main circuit.

SERIES WINDING
On an electromagnet or a field core, the winding connected in series with the main circuit or with the armature

SERVICE WIRES
Wires connecting the interior circuits of a house or building with the outside supply circuit.

SET SPARK IGNITION
An ignition system in which there is no provision for advancing and retarding the time of sparking; in which the spark setting has a permanent advance.

SHEATHING OF A CABLE
The outside covering which protects a cable from mechanical injury or from the effects of water, oils, acids, etc.

SHEDDING OF BATTERY PLATE
Dropping off of the active material from the plates in a storage battery.

SHELL TRANSFORMER
A transformer in which the iron core is built around the outside of the windings.

SHELLAC
An insulating liquid made of gums dissolved in alcohol.

SHOE
In an electric railway car or locomotive, the contact piece that slides along the third rail to collect current.

SHORT CIRCUIT
An accidental connection of low resistance between the two sides of a circuit so that little or no current flows through the current consuming device in the circuit.

SHORT SHUNT
In a compound wound machine, a connection of the shunt winding directly across the armature circuit so that the shunt field current does not flow through the series field.

SHORT TIME RATING
The rating at which an electric device can operate when making frequent stops of sufficient length to allow reasonable cooling.

SHUNT
One of the current paths in a parallel circuit.

SHUNT FOR AMMETER
See ammeter shunt.

SHUNT COIL
In an electromagnet or a field winding, the coil connected in parallel and through which only a part of the current flows.

SHUNT FIELD
A field winding connected in parallel with the armature circuit, connected across the brushes.

SHUNT GENERATOR
A generator whose field winding is in parallel with the armature circuit, connected across the brushes so that only a part of the generated current flows through the winding.

SHUNT MOTOR
A motor whose field winding is in parallel with its armature circuit.

SHUNT RATIO
The ratio of current through a shunt to the current through the whole circuit.

S H U N T   W I N D I N G
On an electromagnet or a field core, the winding connected in parallel with the main circuit or with the armature.

S H U N T E D
Connected in parallel, forming a shunt.

S I D E   C I R C U I T
The two-wire circuit that forms one side of a phantom circuit in telegraphy or telephone.

S I L I C O N   B R O N Z E
Bronze containing silicon and sodium. It is used for wires and cables where mechanical strength and resistance to wear are needed.

S I L I C O N   S T E E L
Steel alloyed with silicon. It has a low hysteresis and eddy current loss.

S I L K   C O V E R E D
Having an insulating covering of silk threads.

S I L V E R
A metal having a lower electrical resistance than copper. It is sometimes used for contact points.

S I M P L E   C I R C U I T
A circuit connecting one source with a current consuming device.

S I M P L E   M A G N E T
A one-piece magnet, as distinguished from a compound magnet of two or more pieces.

S I M P L E   P E R I O D I C   C U R R E N T
A current whose voltage and amperage go through a regular rise and fall in value.

S I N E   W A V E
An alternating current wave form following the curve of sines. The ideal form of an alternating wave.

S I N G L E   C O N T A C T   L A M P
A lamp whose base and socket are designed for use in a single center contact point with the other side of the circuit completed through the side of the base.

S I N G L E   P H A S E
In alternating current work, having but one phase; but one wave. (See phase.)

S I N G L E   P H A S E   C I R C U I T
A circuit carrying a single alternating current.

S I N G L E   P H A S E   G E N E R A T O R
An alternating current generator producing a current with only one phase or wave.

S I N G L E   P H A S E   M O T O R
An alternating current motor operating on one phase of alternating current.

SINGLE PHASE TRANSFORMER
A transformer operating with a single phase alternating current.

SINGLE-POLE
Connected with only one conductor in a circuit or with only one side of a circuit.

SINGLE-POLE CUTOUT
A single fuse in one side of curcuit.

SINGLE-POLE SWITCH
A switch having but one contact.

SINGLE REDUCTION
Having but one pair of gears, pulleys, sprockets, etc., between which there is a reduction of speed.

SINGLE STROKE BELL
An electric bell which is struck only once for each time the bell circuit is closed.

SINGLE THROW
In a knife switch, having but one contact against which the blade can be brought. See double-throw.

SINGLE-WIRE CIRCUIT
A circuit in which one side is carried through ground, requiring but a single wire for the other side.

SINUSOIDAL CURRENT
An alternating current whose wave form is represented by a sinusoid curve.

SIX PHASE CIRCUIT
Alternating current circuits carrying currents whose phase difference is a sixth of a cycle, 60 degrees.

SKIN EFFECT
The effect of an alternating current in producing opposing currents at the center of a conductor so that the current to be carried is forced to the outside of the conductor.

SLEEVE JOINT
A joint made by slipping the ends of two conductors into a short length of tubing.

SLEEVING
A small tube of woven cotton which is slipped over wires to provide insulation.

SLIDE WIRE BRIDGE
A form of Wheatstone bridge in which the known resistance is varied by moving a sliding contact.

SLIDING CONTACT
A contact piece which may be moved across a series of contacts or along the length of a conductor.

SLIP RING
A ring placed on a rotor which conducts the current from the rotor to an external circuit.

SNAP SWITCH
A rotary switch in which the contacts are quickly made and quickly broken by the action of a small coiled spring operated by the button or handle.

SOAKING CHARGE
In storage battery work, a long charge at a low rate which removes excess sulphate from the plates.

SOCKET FOR LAMP
The receptacle or opening into which the base of an incandescent lamp fits to complete the electrical connections.

SOFT DRAWN COPPER WIRE
Copper wire that has been softened by annealing.

SOFT IRON VANE METER
A meter in which a piece of soft iron is magnetized and is acted upon by a magnet.

SOLENOID
A coil or winding of several layers of conductors which are insulated from each other.

SOLENOID AMMETER
An ammeter whose pointer is moved by drawing a plunger into a solenoid against the action of gravity or a spring.

SOLENOID CORE
The soft iron around which a solenoid is wound and in which are concentrated the magnetic lines of force.

SOLID WIRE
A conductor in one piece, as distinguished from stranded or braided conductors.

SPACE CHARGE
In a hot cathode tube it is the current-limiting effect of the electron cloud in the region of the cathode.

SPACE FACTOR
In a magnet winding, the ratio of the space filled by the active conductor to the total space occupied by the winding and its insulation.

SPARK ADVANCE AND RETARD
A change of the instant at which an ignition spark takes place with reference to the position of the engine piston in its stroke.

SPARK COIL
An induction coil giving a high-tension current from a secondary winding for a jump spark, or a self-induced current for a make-and-break spark.

SPARK CONDENSER
A condenser connected across two contacts to reduce sparking as they open their circuit.

S P A R K   G A P

Two points, rods or balls, between which a spark is caused to pass by a high voltage current.

S P A R K   P L U G

In ignition work, a metal shell screwing into the cylinder wall and carrying an insulated center conductor from the end of which a high-tension spark passes to the shell and to ground.

S P A R K   V O L T A G E

The lowest voltage at which a spark will pass between two conductors through air or other insulation.

S P A R K L E S S   C O M M U T A T I O N

Operation of a generator or motor so that there is no sparking at the brush contact on the commutator.

S P E C I F I C

Being measured with reference to certain exact conditions such as a certain size of conductor, etc.

S P E C I F I C   G R A V I T Y

The ratio of the weight of a given volume of any liquid or solid substance to the weight of an equal volume of water, or of any gas to an equal volume of air.

S P E C I F I C   I N D U C T I V E   C A P A C I T Y

The ratio of the change produced in a dielectric to the electromotive force that produces the change.

S P E C I F I C   M A G N E T I C   R E L U C T A N C E

The reluctance of a centimeter cube of the magnetic material being measured.

S P E C I F I C   R E S I S T A N C E

The resistance through a centimeter cube of the substance measured.

S P H E R E   G A P

A spark gap formed between two balls or spheres on the ends of the conductors.

S P I R I L L A

A bacterium shaped like a corkscrew.

S P L I C E   B O X

A box in which cable joints and connections are made.

S P L I T   P H A S E

Currents of different phases obtained from a single phase circuit by use of reactances.

S P L I T   P O L E   C O N V E R T E R

A converter using additional field poles or divided field poles for controlling the voltage.

S P O N G E   L E A D

Pure metallic lead in a porous form. It forms the active material of the

negative plate in a lead-acid storage battery.

S P O R E
A resting cell of certain bacteria.

S P O T   W E L D I N G
Electric welding in which two parts are joined by welding small spots on their adjacent flat surfaces.

S P U R I O U S   R E S I S T A N C E
The resistance to alternating current in excess of the ohmic resistance of the conductor.

S Q U A R E   M I L
A measure or area equal to a square which is one thousandth of an inch on a side. The one millionth part of a square inch.

S T A G G E R I N G   O F   B R U S H E S
Placing two or more brushes so that they slightly overlap each other at their sides.

S T A N D A R D   O H M
A wire having a resistance of exactly one. ohm and used for comparing and calibrating.

S T A N D A R D   R E S I S T A N C E
A carefully graduated resistance used for comparing with unknown resistances and for calibrating instruments.

S T A R T I N G   B O X
A rheostat used for starting an electric motor.

S T A R T I N G   C U R R E N T
The current in amperes required for cranking an automobile engine with an electric starting motor.

S T A R T I N G   M O T O R
A direct current, series wound, electric motor suitable for cranking automobile engines.

S T A R T I N G   R A T E
In storage battery charging, the rate in amperes that is used from the beginning of a charge until the cells start to gas.

S T A R T I N G   T O R Q U E
The maximum torques or turning effort an electric motor can exert in starting its load from a standstill, or the power required to start a load.

S T A R T I N G   W I N D I N G
The winding that starts the motor.

S T A T I C   C H A R G E
A quantity of electricity existing as a charge on conductors or on the plates of a condenser.

S T A T I C   E L E C T R I C I T Y
Electricity at rest, such as in the charge of a condenser, as distinguished from the electric current which is electricity in motion.

STATIC GENERATOR
A generator for the production of frictional electricity.

STATIONARY TRANSFORMER
A transformer in which all the parts and windings are stationary.

STATOR
The stationary part of an electric machine. The moving part is called the rotor.

STEADY CURRENT
A direct current whose voltage does not rise or fall.

STEP-DOWN
Reducing the voltage from a higher to lower value.

STEP-UP
Increasing the voltage from a lower to a higher value.

STORAGE BATTERY
A number of storage cells in a single case and connected with each other to give the desired voltage and current capacity.

STRAIN
The change of shape, size, or condition of a substance produced by stress.

STRANDED CONDUCTOR
A conductor composed of a number of smaller conductors or wires.

STRAY FIELD
In the magnetic circuit of a field, the lines of force that do not pass through the armature conductors and therefore do no useful work.

STRAY FLUX
Any magnetic lines of force that pass out of the part of the magnetic field circuit in which useful work is done.

STRENGTH OF CURRENT
The number of amperes of current.

STRENGTH OF MAGNETISM
The magnetic flux.

STRESS
Any force or action that tends to make a change of size, of shape, or of condition in a substance.

STRIP FUSE
A fuse formed of a flat conductor.

STRIPPING
In electroplating work, removing the old coating or plating from metal parts. Removing the insulation from wire.

STUB'S WIRE GAUGE
The Birmingham wire gauge, a gauge used for measurement of iron wire sizes.

SULPHATE
Sulphate of lead. This compound is formed from both the positive and the negative plate material in lead-acid storage batteries on discharge.

SULPHATION OF BATTERY
The formation of more sulphate of lead in the discharge of lead-acid storage battery than can be turned back into active material upon charging the battery.

SULPHURIC ACID
The acid used, when diluted with water, as the electrolyte in the lead-acid storage battery and in other types of electric cells.

SUPERPOSED CIRCUIT
A circuit completed through a part of another circuit used for a different purpose but allowing both functions to take place at the same time.

SURFACE LEAKAGE
Leakage of current across the surface of an insulator.

SURGE
A rapid change in voltage.

SURGE IMPEDANCE
The impedance due to inductance and capacity in an alternating current circuit.

SUSCEPTANCE
In an alternating current circuit, the wattless part of the admittance.

SUSCEPTIBILITY
The relative ability of a material to allow magnetism to be induced in it by magnetomotive force.

SUSPENSION CABLE
An insulator through which a conductor is passed and which is hung from a supporting wire.

SUSPENSION INSULATOR
An insulator attached to a support above and carrying a conductor below.

SWITCH
A device for opening, closing or changing the connections in electric circuits.

SWITCH BLADE
The movable part of a knife switch, the knife.

SWITCH BOARD
An insulating panel for mounting electric switches, instruments, meters, and connections of all kinds.

SWITCH PLUG
A metal plug which, when pushed into a socket, completes or breaks an electric circuit.

S Y M B O L
A letter or other sign that has been adopted and is understood to stand for some certain value of measurement.

S Y N C H R O N I Z E R
A device for indicating when alternating current machines are synchronous or in phase.

S Y N C H R O N I Z I N G   T O R Q U E
A load which tends to bring two alternators into phase with each other.

S Y N C H R O N O S C O P E
An instrument which shows whether or not two machines are in synchronism, and whether the one to be connected to a circuit lags or leads.

S Y N C H R O N O U S
In alternating current work, having the same frequency and the same phase.

S Y N C H R O N O U S   C O N D E N S E R
An electric machine whose field strength may be changed in order to change the power factor in an alternating current system or to change the lead voltage in such a system.

S Y N C H R O N O U S   C O N V E R T E R
A rotary converter.

S Y N C H R O N O U S   G E N E R A T O R
An alternating current generator whose speed is in proportion to the frequency of its current.

S Y N C H R O N O U S   M A C H I N E
An alternating current machine whose frequency is in proportion to the frequency of its current.

S Y N C H R O N O U S   M O T O R
An alternating current motor whose speed is in proportion to the frequency of its current supply.

S Y R I N G E   H Y D R O M E T E R
A hydrometer carried in a syringe so that the liquid to be tested may be drawn up into the barrel of the syringe.

T .
An abbreviation for "time", seconds.

T A C H O M E T E R
An instrument which measures and indicates the speed of a rotating part, a form of speed indicator.

T A N D E M   D R I V E
Two or more machines placed end to end with the shaft of one coupled directly to the shaft of another.

T A N G E N T   G A L V A N O M E T E R
A galvanometer whose needle is deflected by the current being measured while the deflection is opposed by the earth's magnetism.

TANTALUM FILAMENT LAMP
An incandescent electric lamp having a filament of the metal tantalum.

TAP
A small circuit or conductor connected to a main supply circuit.

TAP CIRCUIT
A circuit taking current directly from a branch circuit to a current consuming device without the use of switches or cutouts.

TAPERING CHARGE
In storage battery work, a charge at constant voltage so that the amperage grows less as the battery voltage rises toward full charge.

TARGET
A visible part connected to some moving part, such as to the armature of a magnet, to indicate its movement.

TELEPHONE CABLE
Annealed copper wire which has been tinned before the insulation is applied.

TELEPHONE CONDENSER
Any condenser used in a telephone circuit. It is usually of the rolled paper and foil type with paraffin insulation.

TELEPHONE FUSE
A cartridge fuse, usually of 5 to 10 ampere capacity, used in telephone circuits.

TELEPHONE JACK
A form of switch which breaks one or more circuits while completing others through the insertion of a plug in a socket so that the various contacts are operated.

TEMPERATURE COEFFICIENT
The rate of change in the resistance of a conductor with change in its temperature.

TEMPERATURE CORRECTION
The correction made in the apparent reading of any value, such as resistance or specific gravity, to make up for the change in that value caused by changes in temperature.

TEMPERATURE LIMIT
The temperature at which there is some certain change, such as the greatest allowable resistance, in an electrical instrument.

TERMINAL
A metal piece attached to the end of a wire or cable so that a secure connection of low resistance may be made to another part of the circuit. Also the part attached to a source or a current consuming device for the attachment of wires to it.

TERMINAL VOLTAGE
Voltage measured between the terminals of an electrical source or a current consuming device.

TESLA COIL
An induction coil or transformer for high frequency currents. It has no iron core.

TEST CLIP
A spring clip attached to the end of a wire from which it is desired to make a temporary connection through the clip to a circuit or to a conductor.

TEST LAMP
An incandescent lamp bulb and base with two wires attached so that the lamp may be temporarily inserted in a circuit for testing purposes.

TEST POINT
A sharp metal prod attached to the end of a conductor so that it may temporarily be connected to a circuit for testing purposes.

TEST SET
An set of electrical measuring instruments mounted for convenient use in making tests.

TESTING TRANSFORMER
A transformer inserted in a wiring system for the purpose of locating short circuits, grounds etc.

THERMOCOUPLE
Two or more metallic plates welded together, in which, under the influence of heat, an electric current is produced.

THERMO-ELECTRICITY
Electricity produced by heat.

THERMO-GALVANOMETER
A galvanometer operating by the heating effect of electricity in conductors.

THERMOSTAT
A device made of two different metals fastened together so that their unequal expansion when heated bends the combination and opens or closes contacts in a circuit.

THERMOSTATIC REGULATION
Regulation of a generator's output by means of a thermostat which acts to insert resistance or take it out of the field circuit with changes of the generator's temperature.

THIRD BRUSH GENERATOR
A direct current generator whose output is controlled by third brush regulation.

THIRD BRUSH REGULATION
Control of a direct current generator's output by the reduction in a field current taken through an extra brush, as the effect of armature reaction at high speeds reduces the voltage at this extra brush.

THIRD RAIL
A rail placed a few inches above the track rails and through which current is taken into the motor circuits of an electric car or locomotive through

contact shoes sliding along the third rail.

THREAD RUBBER SEPARATOR
A storage battery plate separator made of hard rubber through which pass many thousands of fine cotton threads to allow circulation of the electrolyte.

THREE PHASE CIRCUIT
Alternating current circuits carrying currents whose phase difference is one-third of a cycle.

THREE PHASE GENERATOR
An alternating current generator furnishing current to a three phase circuit.

THREE PHASE MOTOR
An alternating current motor operating on a three phase circuit.

THREE-WAY SWITCH
A switch which will complete a circuit through any one of three different paths.

THREE WIRE CIRCUIT
An electric circuit connection in which a neutral conductor is used.

THREE WIRE GENERATOR
A direct current generator whose neutral wire is connected to the middle point of a balancer coil which is connected across the armature windings.

THROW-OVER SWITCH
A double-pole switch that may be quickly thrown from one circuit connection to another.

TIME CONSTANT
The length of time it takes the current in a circuit to come up to a certain value with a given voltage applied to the circuit.

TIME SWITCH
A switch operated by clock work to open or close at a certain time.

TIMER
The device which closes and opens a primary ignition circuit through a rotating contact to determine the time at which the spark takes place, the commutator.

TINNED WIRE
Copper wire covered with a coating of tin to prevent the materials in the insulation from affecting the copper itself.

TIP SIDE OF WIRE
In telephone work, the conductor connected to the tip side of the jack.

TORQUE
The turning or twisting effort exerted on a shaft; measured in units such as the foot-pound.

TORSION BALANCE
A device for measuring the repulsion between magnets or conductors carrying

electric charges by their twisting effect on a wire.

TORSION DYNAMOMETER
A dynamometer which measures the torque of a machine by the effect produced in twisting a spring in the dynamometer.

TOURING SWITCH
In an automobile starting and lighting system, a switch that may be opened to stop the generator from charging the battery.

TRACK CIRCUIT
In electric railway work, the circuit through the rails and their bonds.

TRACK RETURN
In electric railway work, a return circuit completed through the rails and bonds.

TRACTIVE MAGNET
An electromagnet used to cause motion in a part attracted by the magnet so that work is done.

TRAIN LIGHTING BATTERY
A storage battery adapted for use in the electric lighting systems on railway trains.

TRANSFORMER
A device used to change alternating current from one voltage to another.

TRANSFORMER COIL
An induction coil with two windings.

TRANSFORMER COIL MAGNETO
An ignition magneto whose low tension current is used to produce high-voltage in an outside transformer coil.

TRANSFORMER EFFICIENCY
The ratio of the electric power of the current going into a transformer to the power of the secondary circuit from the transformer.

TRANSFORMER LOSS
The difference between the power of the current used by a transformer and the power of the current produced by the transformer.

TRANSFORMER OIL
Oil used to fill the space around transformer windings and cores. It provides insulation and also helps to carry away the heat.

TRANSFORMER RATIO
The ratio of the voltage secured from a transformer to the voltage supplied to that transformer.

TRANSITE
A hard, tough insulating material used where there is little or no moisture.

TRANSMISSION LINE
The conductors through which high-voltage current is carried for long

distances between the power station and the substations.

TRANSMITTER
The part of a telephone set that receives the voice sounds and allows them to affect the circuit so that the message may be carried.

TRANSPOSITION
Changing the relative positions of wires with reference to each other at different points along a line to avoid induction and electrostatic effects between them.

TRICKLE CHARGE
A long continued charge of a storage battery at a very low rate, usually at one-quarter to one-half ampere.

TUBE INSULATOR
A tubular insulator in which conductors are carried through walls and partitions.

TUNGAR RECTIFIER
A bulb rectifier using a tungar bulb, manufactured or licensed by the General Electric Company.

TUNGSTEN
A very hard metal which resists the effects of arcing and which melts only at high temperatures. It is used for contact points.

TUNGSTEN FILAMENT
An incandescent lamp bulb filament made of the metal tungsten, which may be safely heated to a higher degree than filaments of other materials and which consequently gives more light from the same current.

TUNGSTEN STEEL
Steel alloyed with tungsten, the alloy being commonly used for making permanent magnets.

TWENTY-FOUR HOUR CHARGE RATE
The rate in amperes at which a storage battery may be safely charged from the time it is placed in the charging circuit until the charge is complete.

TWIN CABLE
A cable having two insulated conductors running parallel, without twisting.

TWO-PHASE CIRCUIT
An alternating current circuit carrying currents whose phase difference is one-quarter of a cycle.

TWO-PHASE GENERATOR
An alternating current generator furnishing current for a two-phase circuit.

TWO-PHASE MOTOR
An alternating current motor operating on a two-phase circuit.

TWO-POLE
Connected to, or controlling the current in two conductors or two circuits at the same time.

ULTRA VIOLET RAYS
Light rays beyond the violet color--not visible.

UNBALANCED LOAD
In a light or power distributing system, a greater load on some branches than on others.

UNDERCHARGE OF BATTERY
The condition of a storage battery brought about by insufficient charging current regardless of the amount of discharge.

UNDERCOMPOUNDED
In a compound wound generator, the proportion between the shunt and the compound series windings that allows a drop of voltage as the load increases.

UNDERCUTTING OF COMMUTATOR
Removing the mica insulation between commutator segments to a little distance below the surface to clear the brush contact.

UNDERLOAD CIRCUIT BREAKER
A circuit breaker arranged to open when the current through its circuit drops below a certain value for which the breaker is set.

UNIDIRECTIONAL
Maintaining the same polarity or the same direction of current flow at all times.

UNIPHASE
A single alternating current.

UNIPHASE ALTERNATOR
An alternating current generator producing a single-phase current.

UNIPOLAR ARMATURE
The armature used with an acyclic machine.

UNIPOLAR MACHINE
An acyclic machine.

VACUUM BULB
An electric lamp bulb from which the air has been exhausted and not replaced with another gas.

VACUUM CUTOUT
A reverse current cutout whose contacts are held closed by the vacuum in the intake of an internal combustion engine and which are allowed to open when engine stops and the vacuum drops.

VACUUM IMPREGNATING PROCESS
Filling the spaces in electrical parts with insulating compound which is allowed to flow around the parts while they are in a chamber from which the air is exhausted.

VACUUM TUBE LIGHT
Light produced by currents through vacuum tubes.

VAPOR RECTIFIER
A mercury vapor rectifier.

VARIABLE INDUCTANCE
The inductance in circuits or coils having an iron core whose permeability changes with the change of magnetomotive force.

VARIABLE SPARK
An ignition spark whose time of passing in the cylinder of an engine may be changed in relation to the position of the piston in its stroke.

VARIABLE SPEED GENERATOR
A generator having some system of control which prevents too high an output when the generator is operated at various speeds.

VARIABLE SPEED MOTOR
A series wound motor whose speed changes according to the load it is driving.

VOLT
The unit measure of electrical pressure. Abbreviated "E". Sometimes referred to as "Electromotive Force".

VOLTMETER
An instrument used for measuring voltage.

W.
An abbreviation for Watt.

WATER-PROOF WIRE
Wire having rubber insulation which resists the continued effect of water and dampness.

WATER RHEOSTAT
A resistance formed by inserting the ends of two conductors in a bath of water so that the resistance of the water between the conductors forms the rehostat.

WATT
The practical unit of electrical power. One watt is the power produced by a current of one ampere at a pressure of one volt.

WATT-HOUR
A measure of electrical power. The power of one watt used for one hour.

WATT-HOUR METER
An electrical measuring instrument which indicates power in watt-hours.

WATTMETER
An instrument for measuring the power of an electric current in watts.

WATT-MINUTE
A power of one watt used for one minute.

WATT-SECOND
A power of one watt used for one second.

WAVE
See electric wave.

WAVE FORM
The shape of a curve showing the rise and fall of alternating current through a cycle.

WAVE METER
An instrument for observing the form of an alternating current wave.

WAVE SHAPE
The shape of an alternating current wave as plotted by means of an oscillograph.

WAVE WINDING
An armature winding in which each coil is connected at opposite or nearly opposite points on the commutator.

WEATHERPROOF
Materials insulated with fabrics carrying compounds that resist the action of weather.

WESTON CELL
A primary electric cell used as a standard of voltage. It uses electrodes of mercury and cadmium.

WET STORAGE
Placing a storage battery out of service without removing the electrolyte or the plates from the cells.

WHEATSTONE BRIDGE
A device for measuring a resistance by comparing with known resistance in the bridge.

WINDAGE
The air's resistance or retarding effect against the rotation of an armature.

WIPE CONTACT DISTRIBUTOR
An ignition distributor whose rotor makes a wiping contact with segments through which the high tension current is carried to the spark plug wires.

WIPE SPARK
An electric spark produced by the separation of two conductors which have been wiped across one another.

WIPING CONTACT
An electrical contact made between two parts which slide over one another.

WIRE
A piece of drawn metal, usually used as a conductor.

WIRE FINDER
A galvanometer used to locate the opposite ends of wires in a cable when one end is connected to a circuit.

WIRE GAUGE
A measure of the diameter or size of a wire. The size is expressed in numbers.

WIRING SYMBOLS
Small diagrams which indicate the different kinds of electrical devices and the different ways of making connections in a circuit.

WOOD SEPARATOR
A storage battery plate separator made of wood that has been treated to remove the injurious organic acids.

WOUND POLE
A field pole on which there is a winding, as distinguished from a consequent pole without a winding.

WROUGHT IRON
A kind of iron having great magnetic permeability, or ability to carry magnetism with ease.

X.
A symbol for expressing unknowns.

X-RAY
X-Rays are electro-magnetic waves, or vibrations of very short wave lengths.

Y-CONNECTION
A connection between the inner ends of three alternating current circuits in the form of the letter Y, a star connection.

Z.
A symbol for impedance.

ZERO POTENTIAL
Having neither positive nor negative voltage or pressure.

ZINC-CARBON CELL
A primary electric cell using electrodes of zinc and carbon.